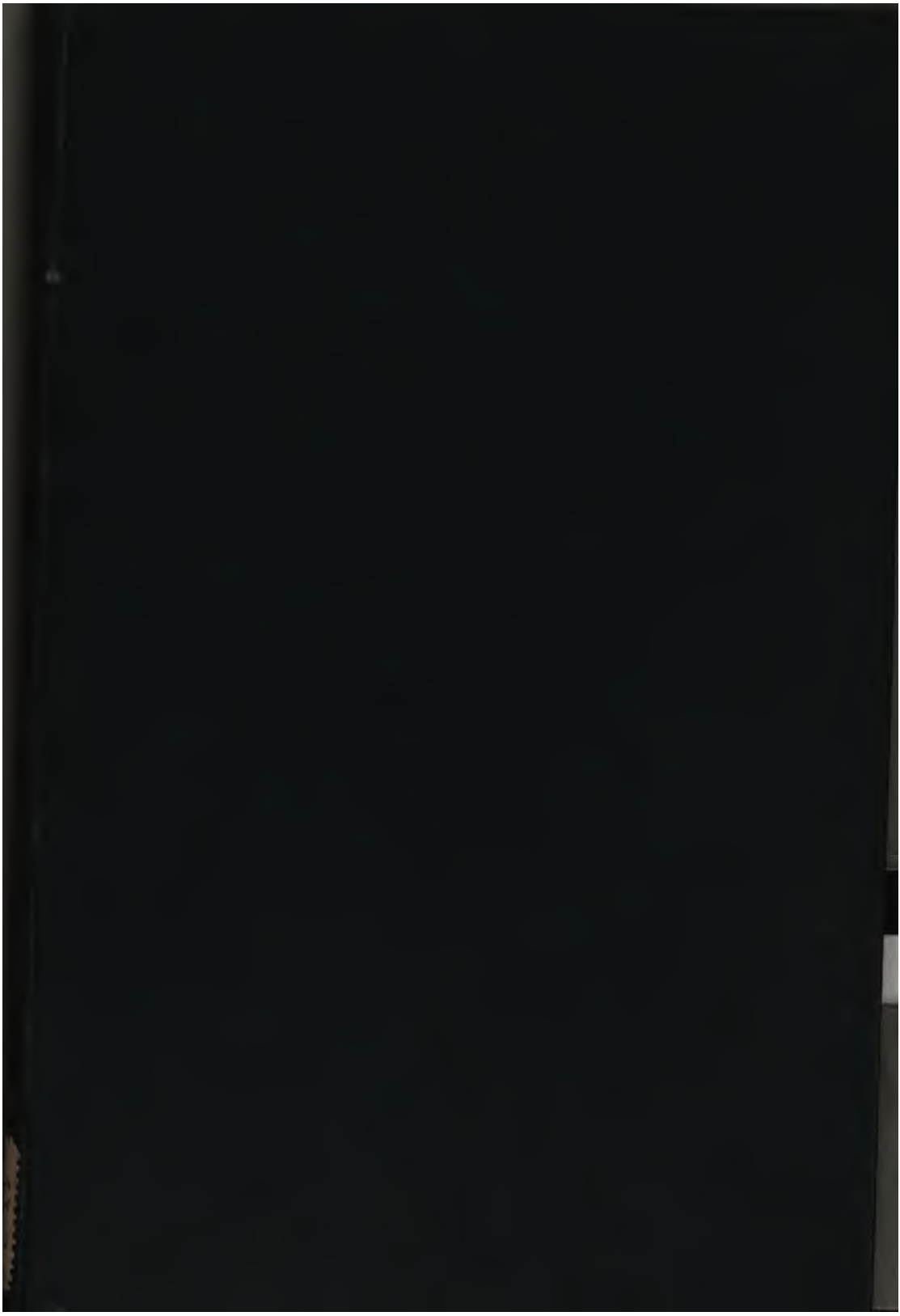


NOTES

ON THE

POST-PLIOCENE GEOLOGY

OF

CANADA;

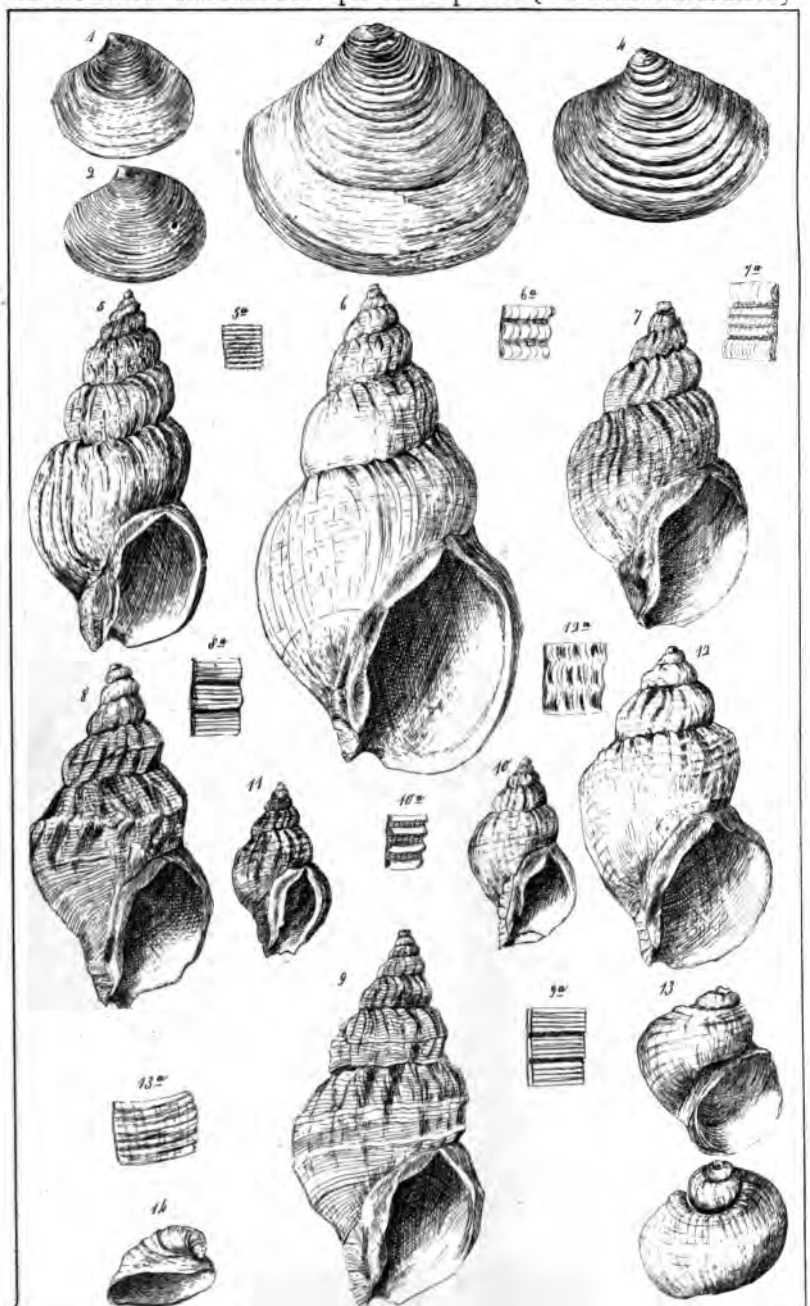
WITH ESPECIAL REFERENCE TO THE CONDITIONS OF ACCUMULATION OF THE DEPOSITS AND THE MARINE LIFE OF THE PERIOD.

BY J. W. DAWSON, LL.D., F.R.S., F.G.S.
Principal of McGill University, Montreal.

(From the Canadian Naturalist, New Series, Vol. VI.)

MONTREAL:
PRINTED BY MITCHELL & WILSON.
1872.

Pl. VII. Critical and Rare Post=pliocene Species. (Canadian Naturalist.)



Drawn on Stone, by A.L.D.

Leggo & Co Lith., Montreal.

NOTES

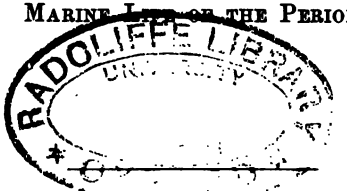
ON THE

POST-PLIOCENE GEOLOGY

OF

CANADA;

WITH ESPECIAL REFERENCE TO THE CONDITIONS OF ACCUMULATION OF THE DEPOSITS AND THE MARINE LIFE OF THE PERIOD.



BY J. W. DAWSON, LL.D., F.R.S., F.G.S.

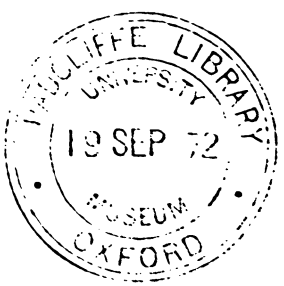
Principal of McGill University, Montreal.

(From the Canadian Naturalist, New Series, Vol. VI.)

MONTREAL:

PRINTED BY MITCHELL & WILSON.

1872.


RADCLIFFE LIBRARY
UNIVERSITY
19 SEP 72
MUSEUM
OXFORD

To SIR WILLIAM E. LOGAN, LL.D., F.R.S.

MY DEAR SIR WILLIAM,

The subject to which this memoir relates is sometimes designated by the term "Superficial" Geology, to distinguish it from the study of those older and more deeply seated sediments with which you are so familiar. It is, however, as you well know, a department of geological investigation connected with some of the most profound and difficult questions of the science, on a few of which it is hoped that light has been thrown by the occasional labours of the last sixteen years, in the rich and instructive deposits of Eastern Canada, summed up in the following pages. I have therefore no hesitation in asking you to accept the dedication of this brochure; more especially as the work of which it is intended to be the completion, so far as I am concerned, was undertaken at your suggestion.

I am with sincere regard and respect,

Yours faithfully,

J. W. DAWSON.

EXPLANATION OF PLATE VII.

This plate, drawn on stone under my own direction, is intended to present, as faithfully as possible, the characters of some of the more rare and critical shells of the Canadian Post-pliocene.

Fig. 1. *Astarte Banksii*—A full-grown specimen of the ordinary type. Riviere-du-Loup.

Fig. 2. *Astarte Laurentiana*—An average full-grown specimen. Montreal.

Fig. 3. *Astarte lactea*—Ordinary type. Portland, Maine.

Fig. 4. *Astarte Elliptica*—A specimen with the ribs extending nearer to the ventral margin than usual. Portland, Maine.

Fig. 5. *Buccinum tenue*—Full-grown specimen. Riviere-du-Loup. 5*a*—Sculpture enlarged.

Fig. 6. *Buccinum cyaneum*—Full-grown specimen. Riviere-du-Loup. 6*a*—Sculpture enlarged.

Fig. 7. *Buccinum undulatum*—(Var. of *undatum*)—Immature shell, broken at lip. Riviere-du-Loup. 7*a*—Sculpture enlarged.

Fig. 8. *Buccinum glaciale*—Tuberculated variety. Riviere-du-Loup. 8*a*—Sculpture enlarged.

Fig. 9. *Buccinum glaciale*—Smooth variety. Riviere-du-Loup. 9*a*—Sculpture enlarged.

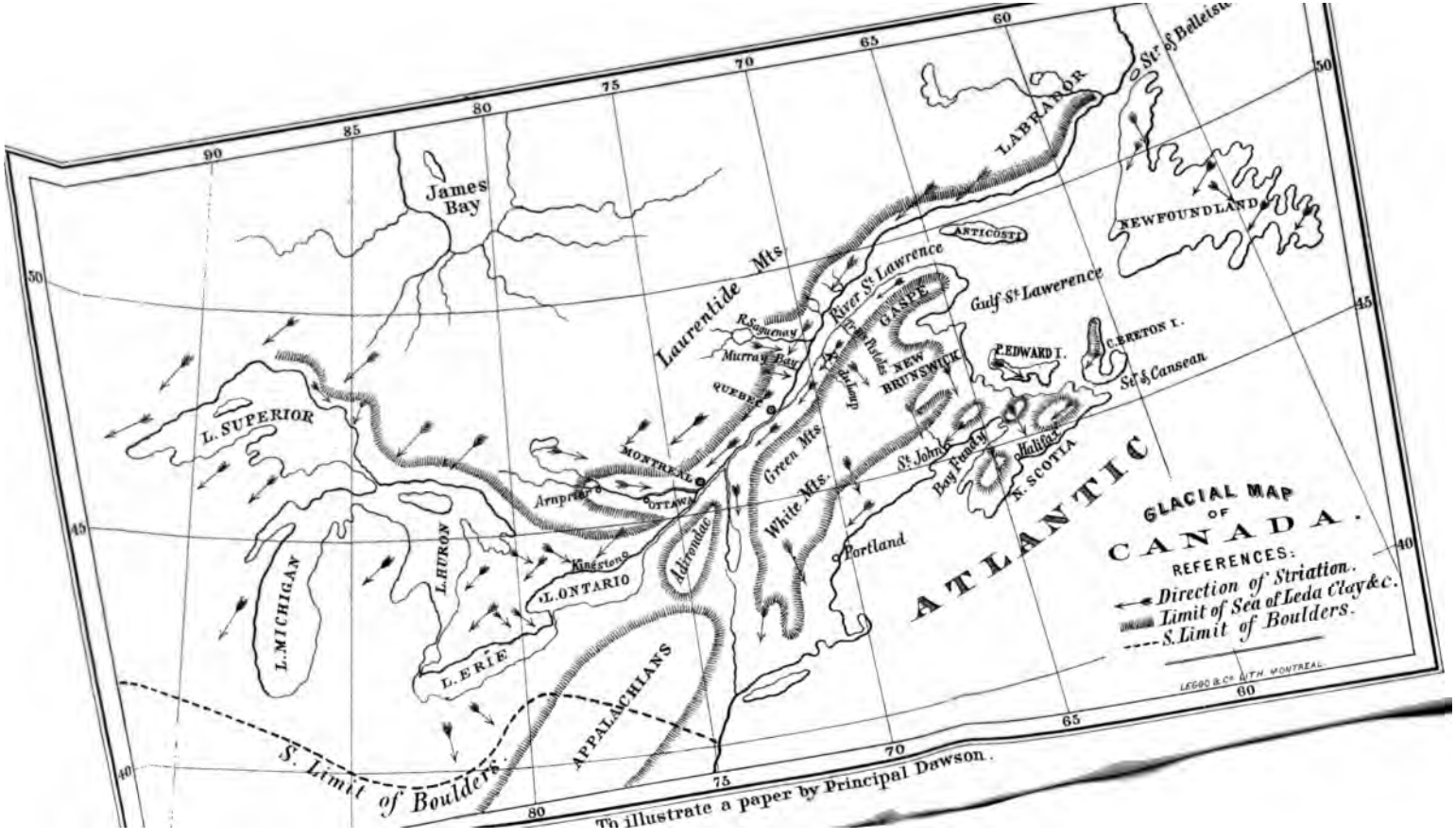
Fig. 10. *Buccinum ciliatum*—(Fabricius, not Gould)—Smooth variety, somewhat decorticated. Montreal. 10*a*—Sculpture enlarged.

Fig. 11. *Buccinum ciliatum*—(Fabricius, not Gould)—Small but mature specimen. Recent Murray Bay.

Fig. 12. *Buccinum Grœnlandicum*—Adult specimen. St. Nicholas. 12*a*—Sculpture enlarged.

Fig. 13. *Choristes elegans*—(Carpenter)—Adult specimen. Montreal. 13*a*—Sculpture enlarged.

Fig. 14. *Capulus commodus*—Pt. Levi, Quebec.



To illustrate a paper by Principal Dawson.

THE

POST-PLIOCENE GEOLOGY

OF CANADA.

By J. W. Dawson, LL.D., F.R.S., F.G.S.

CONTENTS.

Introductory.

When in 1855 the writer, in consequence of accepting the office of Principal of McGill College, was removed from the Carboniferous Districts of Nova Scotia, and thus to some extent debarred from the prosecution of his researches in the carboniferous rocks of that Province and their fossil plants, he determined, with the advice of Sir W. E. Logan, then Director of the Geological Survey of Canada, to take up as an occasional pursuit the study of the Drift Deposits of Canada, a work which had, at

least, this link of connection with previous occupations, that it related in part to marine animals, with which his Zoological studies on the sea coast had made him familiar.

The results of these studies have, in part, been published in the following papers:—

(1.) On the Newer Pliocene and Post-Pliocene of the Vicinity of Montreal.—*Canadian Naturalist*, 1857.

(2.) Additional Notes on the Post-Pliocene Deposits of the St. Lawrence Valley.—*Ib.* 1859.

(3.) On the climate of Canada in the Post-Pliocene Period.—*Ib.* 1860.

(4.) On Post-Tertiary Fossils from Labrador.—*Ib.* 1860.

(5.) On the Geology of Murray Bay (Part 3, Post-pliocene deposits)—*Ib.* 1861.

(6.) Address as President of the Natural History Society of Montreal.—*Ib.* 1864.

(7.) On the Post-pliocene Deposits of Riviere du Loup and Tadoussac.—*Ib.* 1865.

(8.) Comparison of the Icebergs of Belle-isle and the Glaciers of Mont Blanc, with reference to the Boulder-clay of Canada.—*Ib.* 1866.

(9.) On the Evidence of Fossil plants as to the Post-pliocene climate of Canada.—*Ib.* 1866.

In addition to these papers I placed in the hands of Sir W. E. Logan, all my notes and lists of fossils up to 1863, for his Report of that year;* and gave a resumé of the subject, in so far as the Post-pliocene of the Acadian Provinces is concerned, in the second edition of my "Acadian Geology," published in 1868.

Much of the matter contained in these detached publications now requires revision, more especially the lists of fossils; and many additional facts have accumulated. I purpose therefore now to summarize the facts and conclusions of my previous papers and to unite them with the new facts, so as to present as complete a view as possible of the geology of the superficial deposits of Canada. I shall also prepare a complete list of the fossils up to date, with revised nomenclature and synonymy. In this last part of the work I have been aided by Dr. P. P. Carpenter and Mr. Whiteaves. I have had the benefit, in the case of several critical species, of the advice of Mr. J. G. Jeffreys, and Mr. R. MacAn-

* Quoted in this paper as the "Geology of Canada."

drew of London. I am also indebted to Mr. G. S. Brady for determining the Ostracoda, to the Rev. H. W. Crosskey for opportunities of comparing specimens with those of the Clyde Beds, and to Prof. T. R. Jones and Dr. Parker and Mr. G. M. Dawson for help with the Foraminifera.

The present memoir will, I am sure, be welcomed by all who are engaged in the study of the subject to which it relates, if for no other reason, because the Post-pliocene deposits of Canada from their great extent and perfect development, are well fitted to throw light on many of the controversies which are now agitated with regard to these deposits.

It may be proper here to indicate the nomenclature which will be followed. When the whole geological series is divided into Primary, Secondary, and Tertiary, the deposits to which this paper relates are usually named Post-tertiary or Quaternary. These terms are, in my judgment, unfortunate and misleading. If we take the relations of fossils as our guide, then, as Pictet has well remarked, whether we regard the land or the sea animals, there is no decided break between the Newer Pliocene and the Post-pliocene, the changes not being greater than those between the Pliocene and the older Tertiary ages. There is, therefore, no such thing in nature as a Quaternary time distinct from the Tertiary, as the Tertiary is distinct from the Secondary. Where therefore the terms Primary, Secondary, and Tertiary are used, the latter should include the whole time from the Eocene to the modern, inclusive, unless indeed the advent of man be considered an event of sufficient geological importance to warrant a separation of the modern from the Tertiary period. When the terms Palæozoic, Mesozoic and Kainozoic or Neozoic are used, then the two latter terms cover perfectly the Post-pliocene as well as the Eocene, Miocene and Pliocene.

I would therefore include the Post-pliocene in the Neozoic or Tertiary period and define it to be that geological age which is included between the Pliocene and the Recent. From the former it is separated by the advent of the cold or glacial* period, and the accompanying subsidence of the land, as well as by the disappearance of many species of animals and plants. From the latter it is separated by the extinction of many mammalian

* I use the term "glacial" in this paper in its general sense, as including the action of floating ice as well as of land ice.

forms and by the establishment of our continents at their present elevation above the water and with their present fauna and flora and drainage systems. In Canada the absence of the Pliocene deposits and the immediate superposition of the Post-pliocene on the Palaeozoic formations, remove all difficulty on the subject of the beginning of the period. The line of separation between the Post-pliocence and the recent, especially in Western Canada, is less distinct; but in Eastern Canada the upper part of the Post-pliocene is always marine, while the recent deposits are land and fresh-water.

With regard to the subdivisions of the Post-pliocene in Canada, if we confine our attention to the clearly marked marine and glacial beds of the lower part of the St. Lawrence Valley, we have no difficulty in establishing the following divisions, suggested in my paper of 1857:

3. *Saxicava Sand*, shallow-water sand and gravels, equivalent to the Champlain and Terrace epochs in part of Dana, to the modified drift of Hitchcock in part, to the Tertiary sands of Capt. Bayfield; and to the Upper fossiliferous sands and gravels of Scotland and Scandinavia.
2. *Leda Clay*, moderately deep-water clays, equivalent to lower part of Champlain epoch, Dana, and Tertiary clays of Bayfield. Fossiliferous Clays of Scotland and Scandinavia.
3. *Boulder-Clay*.—Hard clay or sometimes sandy clay or sand, with stones and boulders, and not distinctly laminated. Equivalent to Glacial clays of Dana and unmodified drift of Hitchcock. Till and older Boulder clay of Scotland and Scandinavia.

In Lower Canada these three deposits can often be seen in actual superposition, and the order is invariable. In some places all contain marine shells, in others these are limited to the upper part of the Leda clay or the lower part of the Saxicava sand.

In Western Canada, around the great lakes, are extensively distributed beds of clay and gravel, which have been described in the Report of the Geological Survey, and which have afforded fresh-water and land remains only. Of these the Algoma sand and Saugeen clay and sand may possibly correspond in age to the Saxicava sand, and the Erie clay to the Leda clay. This identification is, however, uncertain, as the marine Leda clay has been traced up no further than the vicinity of Kingston, on the St.

Lawrence, and of Arnprior on the Ottawa. Below these points the Valleys of the Ottawa and St. Lawrence present everywhere the deposits above tabulated, in a greater or less degree of completeness. They are connected with the similar deposits of New England, through the valley of Lake Champlain, and across the low lands of Nova Scotia and New Brunswick.

Whittlesey has described the Western Drift Deposits in the Smithsonian Contributions, vol. xv., and according to him the Boulder drift is there the upper member of the series. More recently Prof. Newberry has given a summary of the facts in his Report of the Geological Survey of Ohio for 1869. From these sources I condense the following statements,

The lowest member of the Western drift, corresponding to the Erie clays of the Canadian Report, is very widely distributed and fills up the old hollows of the country, in some cases being two hundred feet or more in thickness. Toward the north these clays contain boulders and stones, but do not constitute a true Boulder-clay. They rest, however, on the glaciated rock surfaces. They have afforded no fossils except drifted vegetable remains.

Above these clays are sands of variable thickness. They contain beds of gravel, and near the surface teeth of elephants have been found. On the surface are scattered boulders and blocks of northern origin, often of great size, and in some cases transported two hundred miles from their original places.

More recent than all these deposits are the "Lake Ridges" marking a former extension of the great lakes. Dr. Newberry considers the Erie clay to be the deposit of a period of submergence following the action of a continental glacier, and he maintains that the old channels now filled with Erie clay are so deep as to indicate that in the earlier glacier period the land was at least five hundred feet higher than its present level. At the close of this period of submergence the boulder drift was deposited by northern currents and ice, and then the land gradually rose to its present level.

The facts thus summed up by Dr. Newberry indicate, in proceeding from the older to the newer.

1. An elevated continent and the erosion of deep valleys.
2. Glaciation of the surface.
3. Filling of the valleys with Erie clay.
4. Distribution over the surface, of boulders and Northern drift.

My interpretation of the phenomena would differ from that of Dr. Newberry in the following particulars—(1) I would refer the continental elevation and the deep erosion to the Pliocene period, before the advent of the glacial epoch. (2) I would refer the glaciated surfaces and the lower part of the Erie clay to the time of the Canadian Boulder-clay, and would regard it as an evidence of subsidence and an ice-laden sea, with the arctic current passing over the continent from the North-East. (3) I would regard the upper part of the Erie clay as equivalent to the Leda clay. (4) I would place the upper and confessedly water-borne drift as the equivalent of the Saxicava sand, and as belonging to the period of elevation.

It is a difficulty, both in Dr. Newberry's view and mine, that marine shells are not found in the Erie clay and surface drift. The following considerations, however, diminish this. (1) The greater part of the Leda clay is very poor in fossils, even near the ocean, and so is the boulder clay. (2) The submergence of a vast continental area under cold water might have continued for a long time before the marine animals could widely spread themselves over it, especially under the unfavourable circumstances of ice erosion. (3) The few and scattered marine remains to be expected in these deposits may have escaped observation. The occurrence of much drift-wood in the Erie clay is also, in my judgment, inconsistent with the occurrence of a general glacier immediately previous to the deposition of the clay.

We may now consider the several members of the Post-pliocene in succession, beginning with the oldest.

GENERAL DESCRIPTION.

1. *The Boulder-Clay.*

Throughout a great part of Canada there is a true "Till," consisting of hard gray clay, filled with stones and thickly packed with boulders. In some places, however, the clay becomes sandy, and in some portions of the carboniferous areas, the paste is an incoherent sand. The mass is usually destitute of any stratification or subordinate lamination; but sometimes in thick beds horizontal lines of different texture or colour can be perceived, and occasionally the clay intervening between the stones becomes laminated, or at least shows such a structure when disintegrated by frost. The Boulder-clay usually rests directly on striated rock surfaces;

but I have observed in Cape Breton a peaty or brown coal deposit, with branches of coniferous trees, to underlie it, and in other places there are deposits of rolled gravel under the Boulder-clay. At the Glen brick-work, near Montreal, a peculiar modified Boulder-clay occurs, consisting of very irregularly bedded sand and gravel, with many large boulders, and only thin layers of clay.

The stones of the Boulder-clay are often scratched and ground into those peculiar wedge-shapes, so characteristic of ice-worked stones. Very abundant examples of this occur in the Boulder clay of Montreal and its vicinity.

At Isle Verte, Riviere du Loup, Murray Bay, Quebec, and St. Nicholas, on the St. Lawrence, the Boulder-clay is fossiliferous, containing especially *Leda truncata*, and often having boulders and large stones covered with *Balanus Hameri* and with Bryozoa, evidencing that they have for some time quietly reposed in the sea bottom before being buried in the clay. This is indeed the usual condition of the Boulder-clay in the lower part of the St. Lawrence River. Further up, in the vicinity of Montreal, it has not been observed to contain fossils, but it presents equally unequivocal evidence of sub-aqueous origin in the low state of oxidation of the iron in the blue clay, which becomes brown when exposed to the weather, and in the brightness of the iron pyrites contained in some of the glaciated stones, as well as in the presence of rounded and glaciated lumps of Utica shale and other soft rocks, which become disintegrated at once when exposed to weathering.

The true Boulder-clay is in all ordinary cases the oldest member of the Post-pliocene deposits, and it is not possible to ascertain the existence of Boulder-clays of different ages, superimposed on one another. It may be observed, however, that in so far as the Boulder-clay is a marine deposit, that which occurs at lower levels is in all probability newer than that which occurs at higher levels. It is also to be observed that boulders with layers of stones occasionally occur in the Leda clay; and that the superficial sands and gravels sometimes contain large boulders; but these appearances are not, I think, sufficiently important to induce any experienced observer to mistake such overlying deposits for the true Boulder clay.

In some localities the stones in the Boulder-clay are almost exclusively those of the neighbouring rock formations, and this is

especially the case at the base of cliffs or prominent outcrops, whence a large quantity of material would be easily derived. In other cases material travelled from a distance largely predominates. Throughout the valley of the Lower St. Lawrence, the gneiss and other hard metamorphic rocks of the Laurentian hills to the north-east are very abundant, and in boulders of large size and much rounded. Occasional instances also occur where boulders have been transported to the northwards; but these are comparatively rare. I have mentioned some examples of this in Acadian Geology, p. 61. Similar instances are mentioned in the Geology of Canada, page 893.

Though the boulder clay often presents a somewhat widely extended and uniform sheet, yet it may be stated to fill up all small valleys and depressions, and to be thin or absent on ridges and rising grounds. The boulders which it contains are also by no means uniformly dispersed. Where it is cut through by rivers, or denuded by the action of the sea, ridges of boulders often appear to be included in it. Those on the Ottawa referred to in the "Geology of Canada," page 895, are very good illustrations, and I have observed the same fact on the Lower St. Lawrence and on the coast of Nova Scotia. It is also observable that these lines and groups of boulders are often not of local material, but of rocks from distant localities, and that a number of the same kind seem often to have been deposited together in one group.

Loose boulders are often found upon the surface, and sometimes in great numbers. In some instances these may represent beds of boulder clay removed by denudation. In other cases they may have been derived from the overlying members of the formation, or may have been deposited on the surface, without any covering of clay or gravel. In "Acadian Geology," p. 64, I have illustrated the manner in which large stones, sometimes 8 feet or more in diameter, are moved by the coast ice and sometimes deposited on the surface of soft mud, and I have had occasion to verify the observations of the same kind made by Admiral Bayfield, and quoted by Sir C. Lyell in the "Principles of Geology." Lastly, on certain high grounds there are large loose boulders, which have probably been moved to their present positions by means of land ice or glaciers.

The Boulder-clay not only presents, as above stated, indications of successive beds, but it occasionally contains surfaces on which lie large boulders striated and polished on the upper surface, in

the manner of the pavements of boulders described by Miller, as occurring in the Till of Scotland. These appearances are, however, rare, and few opportunities occur for observing them.

A very general and important appearance is the polishing and striation of the underlying rocks usually to be observed under the Boulder-clay, and which is undoubtedly of the same character with that observed under Alpine glaciers. This continental striation or grooving is obviously the effect of the action of ice, and its direction marks the course in which the abrading agent travelled. This direction has been ascertained by the Canadian and United States Surveys, and by local observers, over a large part of Eastern America, and it presents some broad features well deserving attention. A valuable table of the direction of this striation is given in the Geology of Canada, which I may take as a basis for my remarks, adding to it a few local observations of my own.* The table embraces one hundred and forty five observations, extending along the valleys of the St. Lawrence and the Ottawa and the borders of the great lakes. In all of these the direction is south, with an inclination to the West and East, or to state the case more precisely, there are two sets of striae, a South-west set and a South-east set. In the table eighty-four are westward of South and fifty-eight are eastward of South, three being due South. It further appears, when we mark the localities on the map, that in the valley of the St. Lawrence and the rising grounds bounding it, the prevailing course is South-west, and this is also the prevalent direction in Western New York, and behind the great Laurentide chain on the North side of Lake Huron. Crossing this striation nearly at right angles, is a second set, which occurs in the neck of land between Georgian Bay and Lake Ontario, in the valley of the Ottawa and in the hilly districts of the Eastern Townships of the Province of Quebec, where it is connected with a similar striation which is prevalent in the valleys of Lake Champlain and the Connecticut River and elsewhere in New England. In New England this striation is said to have been observed on hills 4800 feet high, as for example on Mansfield Mountain, where according to Hitchcock there are striae bearing S. 30° E. at an elevation of 4848 feet. In Nova Scotia and New Brunswick, as

* See also, for the Western districts, Whittlesey's Memoir in the Smithsonian Contributions, and Newberry's Report on Ohio.

in New England, the prevailing direction is South Eastward, though there are also South-west and South striation, and a few cases where the direction is nearly East and West.

It is obvious that such striation must have resulted from the action of a solid mass or masses of ice bearing for a long time on the surface and abrading it by means of stones and sand. It is further obvious that the different sets of striation could scarcely have been produced at the same time, especially when, as is not infrequent, we have two sets nearly at right angles to each other in the same locality. Hence it becomes an important question to ascertain the relative ages of the striation and also the direction in which the abrading force moved.

Taking the valley of the St. Lawrence in the first instance, the crag-and-tail forms of the isolated hills of trap, like the Montreal mountain, with abrupt escarpments to the north-east and slopes of debris to the south-west, the quantity of boulders carried from them far to the south-west, and the prevailing striation in the same direction, all point to a general movement of detritus up the St. Lawrence valley to the south-west. Further, in some cases the striae themselves show the direction of the abrading force. For example, in a fine exposure recently made at the Mile-end quarries, near Montreal, the polished and grooved surface of the limestone shows four sets of striae. The principal ones have the direction of S. 68° W. and S. 60° W. respectively, and the second of these sets is the stronger and coarser, and sometimes obliterates the first. The two other sets are comparatively few and feeble striae, one set running nearly N. and S., and the other N.W. and S.E. These last are probably newer than the two first sets. Now with regard to the direction of the principal sets of striae, this at the locality in question was rendered very manifest by the occurrence of certain trap dykes crossing the limestone at right angles to the striae. The force, whatever it was, had impinged on these dykes from the N. E., and their S. W. side had protected the softer limestone. The locality is to the North-east of the mass of trap constituting the Montreal mountain, and the movement must have been up the St. Lawrence valley from the N.E., and toward the mountain, but at this particular place the striae point West of its mass. This, I have no hesitation in saying, is the dominant direction in the St. Lawrence valley, and it certainly points to the action of the arctic current passing up the valley in a period of submergence. Fur-

ther, it is the Boulder-clay connected with this S. W. striation that has hitherto proved most rich in marine shells.

If, however, we pass from the St. Lawrence Valley up the valleys which open into it from the North, as for example the gorge of the Saguenay, the Murray Bay River, or the Ottawa River, we at once find a striation nearly at right angles to the former, or pointing to the South-east.

At the mouth of the Saguenay, near Moulin Bode, are striae and grooves on a magnificent scale, some of the latter being ten feet wide and four feet deep, cut into hard gneiss. Their course is N. 10° W. to N. 20° W. magnetic, or N. 30° to 40° W. when referred to the true meridian. In the same region, on hills 300 feet high, are roches moutonnees with their smoothest faces pointing in the same direction, or to the North-west. This direction is that of the valley or gorge of the Saguenay, which enters nearly at right angles the valley of the St. Lawrence. At the month of the Saguenay the Lark Shoals constitute a mass of debris and boulders, both inside and outside of which is very deep water; and many of the fragments of stone on these shoals must have been carried down the Saguenay more than fifty miles.

In like manner at Murray Bay there are striae on the Silurian limestones near Point au Pique, which run about N. 45° W. but these are crossed by another set having a course S. 30° W., so that we have here two sets of markings, the one pointing upwards along the deep valley of Murray Bay River to the Laurentide Hills inland, the other following the general trend of the St. Lawrence valley. The Boulder-clay which rests on these striated surfaces is a dark-coloured Till, full of Laurentian boulders, and holding *Leda truncata*, and also Bryozoa clinging to some of the boulders. In ascending the Murray Bay River, we find these boulder-beds surmounted by very thick stratified clays, with marine shells, which extend upward to an elevation of about 800 feet, when they give place to loose boulders and unstratified drift. About this elevation, the laminated clays meet a ridge of drift like a moraine, crossing the valley, which forms the barrier of a small lake, Petite Lac, and a second similar barrier separates this from Grand Lac. If the valley of Murray Bay River was occupied with a glacier descending from the Laurentian hills inland, which are probably here 3000 to 4000 feet high, this glacier or large detached masses pushed from its foot, must have at one time extended quite to the border of the St. Lawrence, and at

another must have terminated at the borders of the two lakes above mentioned.

On a still larger scale the N. W. and S. E. striation appears in the valley of the Ottawa, and farther west between the head of Lake Ontario and Lake Huron. In these places there is no elevation capable of giving rise to local glaciers, and therefore, as in New England and Nova Scotia, we must ascribe the glaciation either to general ice-laden currents from the North-west, or to the great continental glacier imagined by some geologists.

A most important observation bearing on this subject appears in the Report of Mr. R. Bell, in the region of Lake Nipigon, North of Lake Superior. He observed there the prevailing South-west striation, but with a more westerly trend than usual. Crossing this, however, there was a southerly and S. E. set of striae which were observed to be older than the South-west striae. In some other parts of Canada these striae seem to be newer than the others, but there would be nothing improbable in their occurring both at the beginning and end of the Boulder-clay period.

In summing up this subject, I think it may be affirmed that when the striation and transfer of materials have obviously been from N.E. to S.W., in the direction of the Arctic current, and more especially when marine remains occur in the drift, we may infer that floating ice and marine currents have been the efficient agents. Where the striation has a local character, depending upon existing mountains and valleys, we may on the other hand infer the action of land ice. For many minor effects of striation and of heaping up of moraine-like ridges, we may refer to the presence of lake or coast ice as the land was rising or subsiding. This we now see producing such effects, and I think it has not been sufficiently taken into the account.

As to the St. Lawrence valley, it is evident that its condition during the deposit of the Boulder-clay must have been that of a part of a wide sound or inland sea extending across the continent, and that local glaciers may have descended into it from the high lands on the north and possibly also on the south. During this state of the valley great quantities of boulders were brought down into it, especially from the Laurentide hills, and were drifted along the valley, principally to the south-west. Extensive erosion also took place by the combined action of frost, rain, melting snows, and the arctic current and the waves, and thus was furnished the finer material of the Boulder-clay.

It is further to be observed that oscillations of land must be taken into account in explaining these phenomena. Elevations increasing the height and area of land might increase the space occupied by snow and land ice. Depressions, on the other hand, would bring larger areas under the influence of water-borne ice and marine deposits, and these might take place either in a shallow sea loaded with field and coast ice, or in deeper water in which large icebergs might float or ground. There is reason to believe that such alternations were not infrequent in the Post-pliocene, and that their occurrence will explain many of the complexities of these deposits.

If we adopt the iceberg hypothesis, we must be prepared to consider in connection with this subject a subsidence so great as to place the Laurentides and all but the highest summits of the Appalachians under water. In this case a vast volume of Arctic ice and water would pour over the country of the great lakes to the S.W., while any obstruction occurring to the south would throw lateral currents over the Appalachians to the eastward. If we adopt the glacier hypothesis, we may on the other hand imagine a great movement of land ice to the S.W., westward of the Appalachians, and a separate outward movement eastward from these hills and down the Atlantic slope of America. On either hypothesis there are difficulties in accounting for some sets of striae, but on that last-mentioned I believe them to be insuperable.

It is evident from the descriptions of Smith, Geikie, Jameson, Crosskey, and others, that the Boulder-clay of Scotland and Scandinavia corresponds precisely in character with that of Canada, and there, as in America, the theory of a continental glacier has been resorted to for its explanation. The objections to this hpyothesis are very ably stated by Mr. Milne Home in a paper on the "Boulder-clay of Europe," in the Transactions of the Royal Society of Edinburgh, 1869.

To this period and these causes must also be assigned the excavation of the basins of the great American lakes. These have been cut out of the softer members of the Silurian and Devonian Formations; but the mode of this excavation has been regarded as very mysterious; and like other mysteries has been referred to glaciers. Its real cause was obviously the flowing of cold currents over the American land during its submergence. The lake-basins are thus of the same nature with the deep hollows

intervening between the banks cast up by the Arctic currents on the present American coast, and like those deep channels of the Arctic current in the Atlantic recently explored by Dr. Carpenter. Their arrangement geographically as well as their geological relations, correspond with this view.

Another consideration with regard to the great lakes deserves notice. Dr. Newberry has collected many facts to show that the lake basins are connected with one another and with the sea by deep channels now filled up with drift deposits. It is therefore possible that much of the erosion of these basins may have occurred before the advent of the glacial period, in the Pliocene age, when the American continent was at a higher level than at present. Dr. Newberry has given in the Report in the Geology of Ohio a large collection of facts ascertained by boring or otherwise, which go far to show that were the old channels cleared of drift and the continent slightly elevated, the great lakes would be drained into each other and into the ocean by the valleys of the Hudson and the Mississippi, without any rock cutting, and if the barrier of the Thousand Islands were then somewhat higher, the St. Lawrence valley might have been cut off from the basin of the great lakes.

I shall close the discussion of this subject by quoting from one of the papers above referred to, my views in 1864; reserving, however, some points respecting the present action of floating ice, to which I shall refer in the sequel.

"Our American lake-basins are cut out deeply in the softer strata. Running water on the land would not have done this, for it could have no outlet; nor could this result be effected by breakers. Glaciers could not have effected it; for even if the climatal conditions for these were admitted, there is no height of land to give them momentum. But if we suppose the land submerged so that the Arctic current, flowing from the northeast, should pour over the Laurentian rocks on the north side of Lake Superior and Lake Huron, it would necessarily cut out of the softer Silurian strata just such basins, drifting their materials to the southwest. At the same time, the lower strata of the current would be powerfully determined through the strait between the Adirondac and Laurentide hills, and, flowing over the ridge of hard rock which connects them at the Thousand Islands, would cut out the long basin of Lake Ontario, heaping up at the same time in the lee of the Laurentian ridge, the great mass of boulder-

clay which intervenes between Lake Ontario and Georgian Bay. Lake Erie may have been cut by the flow of the upper layers of water over the Middle Silurian escarpment; and Lake Michigan, though less closely connected with the direction of the current, is, like the others, due to the action of a continuous eroding force on rocks of unequal hardness."

"The predominant southwest striation, and the cutting of the upper lakes, demand an outlet to the west for the Arctic current. But both during depression and elevation of the land, there must have been a time when this outlet was obstructed, and when the lower levels of New York, New England, and Canada were still under water. Then the valley of the Ottawa, that of the Mohawk, and the low country between Lakes Ontario and Huron, and the valleys of Lake Champlain and the Connecticut, would be straits or arms of the sea, and the current, obstructed in its direct flow, would set principally along these, and act on the rocks in north and south and northwest and southeast directions. To this portion of the process I would attribute the northwest and southeast striation. It is true that this view does not account for the southeast striæ observed on some high peaks in New England; but it must be observed that even at the time of greatest depression, the Arctic current would cling to the northern land, or be thrown so rapidly to the west that its direct action might not reach such summits."

"Nor would I exclude altogether the action of glaciers in eastern America, though I must dissent from any view which would assign to them the principal agency in our glacial phenomena. under a condition of the continent in which only its higher peaks were above the water, the air would be so moist, and the temperature so low, that permanent ice may have clung about mountains in the temperate latitudes. The striation itself shows that there must have been extensive glaciers as now in the extreme Arctic regions. Yet I think that most of the alleged instances must be founded on error, and that old sea-beaches have been mistaken for moraines. Even in the White Mountains the action of the ocean-breakers is more manifest than that of ice almost to their summits; and though I have observed in Canada and Nova Scotia many old sea-beaches, gravel-ridges, and lake-margins, I have seen nothing that could fairly be regarded as the work of glaciers. The so-called moraines, in so far as my observation extends, are more probably shingle beaches and bars, old coast-

lines loaded with boulders, or "ozars." Most of them convey to my mind the impression of ice-action along a slowly subsiding coast, forming successive deposits of stones in the shallow water, and burying them in clay and smaller stones as the depth increased. These deposits were again modified during emergence, when the old ridges were sometimes bared by denudation, and new ones heaped up."

"I conclude these remarks with a mere reference to the alleged prevalence of lake-basins and fiords in high northern latitudes, as connected with glacial action. In reasoning on this, it seems to be overlooked that the prevalence of disturbed and metamorphic rocks over wide areas in the north is one element in the matter. Again, cold Arctic currents are the cutters of basins, not the warm surface-currents. Further, the fiords on coasts, like the deep lateral valleys of mountains, are evidences of the action of the waves rather than of that of ice. I am sure that this is the case with the numerous indentations of the coast of Nova Scotia, which are cut into the softer and more shattered bands of rock, and show, in raised beaches and gravel ridges like those of the present coast, the levels of the sea at the time of their formation."

2. *The Leda Clay.*

This deposit constitutes the subsoil over a large portion of the great plain of Lower Canada, varying in thickness from a few feet to 50 or perhaps even 100 feet in thickness, and usually resting on the Boulder clay, into which it sometimes appears to graduate, the material of the Leda clay being of the same nature with the finer portion of the paste of the Boulder clay. Its name is derived from the presence in it of shells of *Leda truncata*, often to the exclusion of other fossils, and usually in a perfect state with both valves united.

The Leda clay in its recent state is usually gray in colour, unctuous, and slightly calcareous. Some beds, however, are of a reddish hue; and in thick sections recently cut, it can be seen to present layers of different shades and occasional thin sandy bands, as well as layers studded with small stones. It sometimes holds hard calcareous concretions, which, as at Green's creek on the Ottawa, are occasionally richly fossiliferous, but more usually are destitute of fossil remains. When dried, the Leda clay becomes of stony hardness, and when burned it assumes a brick-red colour. When dried and levigated it nearly always affords some foraminifera and shells of ostracoids; and in this as well as in its colour

and texture, it closely resembles the blue mud now in process of deposition in the deeper parts of the Gulf of St. Lawrence.

The lamination of the Leda clay and its included sand layers, show that it was deposited at intervals, between which intervened spaces when currents carried small quantities of sand over the surface. In these intervals shells as well as sand were washed over the bottom, while ordinarily Leda, Nucula and Astarte burrowed in the clay itself. The layers and patches of stones I attribute to deposit from floating ice, and to the same cause must be attributed the large Laurentian boulders, occasionally though rarely seen imbedded in the clay.

The material of the Leda clay has been derived mainly from the waste of the lower Silurian shales of the Quebec and Utica groups, which occupy a great space in the basin of the Gulf and River St. Lawrence. The driftage of this material has been to the South-west, and in that direction it becomes thinner and finer in texture. The supply of this mud, under the action of the waves, of streams, of the arctic currents and tidal currents, and floating ice, must have been constant, as it now is in the Gulf and River St. Lawrence. It would be increased by the melting of the snows in spring and by any oscillations of level, and it is probably in these ways that we should account for the alternations of layers in the deposit.

The modern deposit in the Gulf of St. Lawrence, the chemical characters and coloration of which I explained many years ago,* shows us that the Leda clay when in suspension was probably reddish or brown mud tinted with peroxide of iron, like that which we now see in the lower St. Lawrence; but like the modern mud, so soon as deposited in the bottom, the ferruginous colouring matter would in ordinary circumstances be deoxidised by organic substances, and reduced to the condition of sulphide or carbonate of the protoxide. This colour, owing to its impermeability, it still retains when elevated out of the sea; but when heated in presence of air, or exposed for some time at the surface, it becomes red or brown. The occasional layers of reddish Leda clay indicate places or times when the supply of organic matter was insufficient to deoxidise the iron present in the mass.

The greater part of the Leda clay was probably deposited in water of from twenty to one hundred fathoms in depth, corres-

* Journal of Geological Society of London, vol. v. pp. 25 to 30.

ponding to the ordinary depths of the present Gulf of St. Lawrence; and as we shall find, this view is confirmed by the prevalent fossils contained in it, more especially the Foraminifera. The most abundant of these in the Leda clay is *Polystomella striato-punctata* var. *arctica*, which is now most abundant at about twenty-five to thirty fathoms. Since, however, the shallow-water marine Post-pliocene beds extend upwards in some places to a height of six hundred feet on the hills on the north side of the St. Lawrence, it is probable that deposits of Leda clay contemporaneous with these high-level marine beds were formed in the lower parts of the plain at depths exceeding one hundred fathoms.

The Western limits of the Leda clay appear to occur where the Laurentian ridge of the Thousand Islands crosses the St. Lawrence, and where the same ancient rocks cross the Ottawa; and in general the Leda clay may be said to be limited to the lower Silurian plain and not to mount up the Laurentian and metamorphic hills bounding it. Since, however, the level of the water, as indicated by the Terraces in Lower Canada, and by the probable depth at which the Leda clay was deposited, would carry the sea level far beyond the limits above indicated, and even to the base of the Niagara escarpment, we must suppose, either—(1) that the supply of this sediment failed toward the west; or (2) that it has been removed by denudation or worked over again by the fresh waters so as to lose its marine fossils; or (3) that the relative levels of the Western and Eastern parts of Canada were different from those at present. As already stated there are indications that the first may be an element in the cause. The second is no doubt true of the clays which lie in the immediate vicinity of the lake basins. There are, as yet no certain evidences of the third; but the facts previously stated on the authority of Dr. Newberry, lend it some countenance; and detailed surveys of the Terraces and raised beaches would be required to determine it. I believe, however, that much more rigorous investigations of the clays of Western Canada are required before we can certainly affirm that none of them are marine.

I believe the Leda clays throughout Canada to constitute in the main one contemporaneous formation. Of course, however, it must be admitted that the deposit at the higher levels may have ceased and been laid dry while it was still going on at lower

levels nearer the sea, just as a similar deposit still continues in the Gulf of St. Lawrence. On the whole, then, while we regard this as one bed stratigraphically, we may be prepared to find that in the lower levels the upper layers of it may be somewhat more modern than those portions of the deposit occurring on higher ground and farther from the sea.

Where the Leda clay rests on marine Boulder-clay, the change of the deposits implies a diminution of ice-transport relatively to deposition of fine sediment from water; and with this more favourable circumstances for marine animals. This may have arisen from geographical changes diminishing the supply of ice from local glaciers, or obstructing the access of heavy icebergs from the Arctic regions. At the present time, for example, the action of the heaviest bergs is limited to the outer coasts of Labrador and Newfoundland, and a deposit resembling the Leda clay is forming in the Gulf of St. Lawrence; but a subsidence which would determine the Arctic current and the trains of heavy bergs into the Gulf, would bring with it the conditions for the formation of a Boulder-clay, more especially if there were glaciers on the Laurentide hills to the north. Where the Leda clay rests on Boulder-clay, which may be supposed to be of terrestrial origin, subsidence is of course implied; and it is interesting to observe that the conditions thus required are the reverse of each other. In other words, elevation of land or sea bottom would be required to enable Leda clay to take the place of marine Boulder-clay, but depression of the land would be necessary to enable Leda clay to replace the moraine of a glacier. I cannot say, however, that I know any case in Canada where I can certainly affirm that this last change has occurred; though on the north shore of the St. Lawrence there are cases in which the Leda clay rests directly on striated surfaces which might be attributed to glaciers; just as in the West the Erie clay occupies this position.

3. *The Saxicava Sand.*

When this deposit rests upon the Leda clay, as is not unfrequently the case, the contact may be of either of two kinds. In some instances the surface of the clay has experienced much denudation, being cut into deep trenches, and the sand rests abruptly upon it. In other cases there is a transition from one deposit to the other, the clay becoming sandy and gradually pass-

ing upwards into pure sand. In this last case the lower part of the sand at its junction with the clay is often very rich in fossils, showing that after the deposition of the clay a time of quiescence supervened with favourable conditions for the existence of marine animals, before the sand was deposited. It is usually, indeed, in this position that the greater part of the shells of our Post-pliocene beds occur; the Saxicava sand being generally somewhat barren, or containing only a few shallow-water species, while the Leda clay is usually also somewhat scantily supplied with shells, except toward its upper layers. Hence it is somewhat difficult to refer a large part of the shells to either deposit, I have however usually regarded the richly fossiliferous deposit as belonging to the Leda clay; and where, as sometimes happens, the clay itself is absent and merely a thin layer rich in fossils separates the Saxicava sand from the Boulder-clay, I have regarded this layer as the representative of the Leda clay.

The Saxicava sand, in typical localities, consists of yellow or brownish quartzose sand, derived probably from the waste of the Potsdam sandstone and Laurentian gneiss, and stratified. It often contains layers of gravel, and sometimes is represented altogether by coarse gravels. It is somewhat irregular in its distribution, forming banks and mounds, partly no doubt in consequence of original irregularities of deposit, and partly from subsequent denudation. In some outlying localities it is liable to be confounded with the modern river sands and gravels. Large travelled boulders often occur in it; but it rarely contains glaciated stones, the stones and pebbles seen in it being usually well rounded.

From the nature of the Saxicava sand, it is obvious that it must be a shallow water deposit, belonging to the period of emergence of the land; and it must have been originally a marginal and bank deposit, depending much for its distribution on the movement of tides and currents. In some instances, as at Cote des Neiges, near Montreal, and on the Terraces on the Lower St. Lawrence, it is obviously merely a shore sand and gravel, like that of the modern beach. Ridges of Saxicava sand and gravel have often been mistaken for moraines of glaciers; but they can generally be distinguished by their stratified character and the occasional presence of animal remains, as well as by the water-worn rather than glaciated appearance of their stones and pebbles.

The Saxicava sand sometimes rests on the Leda clay or Boulder clay and sometimes directly on the rock, and the latter is often striated below this deposit; but in this case there is generally reason to believe that Boulder-clay has been removed by denudation.

4. *Terraces and Inland Sea Cliffs.*

These are closely connected with the deposits last mentioned, inasmuch as they have been formed by the same recession of the sea which produced the Saxicava sand. At Montreal, where the isolated mass of trap flanked with Lower Silurian beds, constituting Mount Royal, forms a great tide-guage for the recession of the Post-pliocene sea, there are four principal sea margins with several others less distinctly marked. The lowest of these, at a level of about 120 feet above the level of the sea at Lake St. Peter, may be considered to correspond with the general level of the great plain of Leda clay in this part of Canada. On this Terrace in many places the Saxicava sand forms the surface, and the Leda and Boulder-clay may be seen beneath it. This may be called at Montreal the Sherbrooke Street Terrace. Another, the Water-work Terrace, is about 220 feet high, and is marked by an indentation on the Lower Silurian limestone. At this level some Boulder-clay appears, and in places the calcareous shales are decomposed to a great depth, evidencing long sub-aerial action. Three other Terraces occur at heights of 386, 440, and 470 feet, and the latter has, at one place above the village of Cote des Neiges, a beach of sand and gravel with Saxicava and other shells. Even on the top of the Mountain, at a height of about 700 feet, large travelled Laurentian boulders occur. On the Lower St. Lawrence, below Quebec, the series of Terraces is generally very distinctly marked, and for the most part the lower ones are cut into the Boulder and Leda clays, which are here of great thickness. I give below rough measurements of the series as they occur at Les Eboulements, Little Mal Bay and Murray Bay, where they are very well displayed. I may remark in general with respect to these Terraces, that the physical conditions at the time when they were cut must have been much the same with those which exist at present, the appearances presented being very similar to those which would occur were the present beach to be elevated.

TERRACES LOWER ST. LAWRENCE.

Heights in English feet, roughly taken with Locke's Level and Aneroid.

Les Eboulements.	Petite Mal Bay.	Murray Bay.
900		
660	748	
479	505	448
		378
325	318	312
226	239	281
		139
116	145	116
		81
22	26	30

With reference to the differences in the above heights, it is to be observed that the Terraces themselves slope somewhat, and are uneven, and that the principal Terraces are sometimes complicated by minor ones dividing them into little steps. It is thus somewhat difficult to obtain accurate measurements. There seems, however, to be a general agreement of these Terraces, and this I have no doubt will be found to prevail very extensively throughout the Lower St. Lawrence. It will be seen that three of the principal Terraces at Montreal correspond with three of those at Murray Bay; and the following facts as to other parts of Canada, gleaned from the Reports of the Survey and from my own observations, will serve farther to illustrate this:

Kemptville,	sand and littoral shells,	250	feet.
Winchester,	do.	300	"
Kenyon,	do.	270	"
Lochiel,	do.	264 & 290	"
Hobbes' Falls, Fitzroy,	do.	350	"
Dulham Mills, De L'Isle,	do.	289	"
Upton,		257	"

The evidence of sea action on many of these beaches, and the accumulation of shells on others, point to a somewhat long residence of the sea at several of the levels, and to the intermittent elevation of the land. On the wider Terraces, at several levels it is usual to see a deposit of sand and gravel corresponding to the Saxicava sand.

In the following table I have endeavoured to represent to the eye the facts observed in the internal plain of the great Lakes, and in the marginal area of the Atlantic slope, with the mode of accounting for them on the rival theories of glacier ice and floating ice.

TABULAR VIEWS OF GLACIAL DEPOSITS AND THEORIES.

Facts observed.		*Theoretical Views.*	
INLAND PLAINS.	MARGINAL AREAS.	GLACIER THEORIES	FLOATING-ICE THEORIES.
Terraces.	Terraces and raised beaches.	Emergence of modern Land.	
Travelled boulders and glaciated stones and rocks. Stratified sand and gravel. (Algoma sand, &c.)	Sand and gravel, with sea shells and boulders. (Saxicava sand).	Shallow Seas and Floating Ice.	
Stratified clay with drift-wood, and a few stones and boulders. (Erie clay.)	Stratified clay with sea shells. (Leda clay). Clay and boulders with or without sea shells. (Boulder-clay).	Deep water with Floating Ice.	
		Submergence of the land.	Much floating ice and local glaciers.
Striated rocks.	Striated rocks.	Great continental mantle of Ice.	Submergence of Pliocene land.
Old channels, indicating a higher level of the land.	Old channels indicating previous dry land.	Erosion by continental glaciers.	Erosion by atmospheric agencies, & accumulation of decomposed rock.

It will be observed that the theoretical views diverge with respect mainly to the Boulder-clay and the striation under the Erie clay, and to the cause of the erosion of valleys in the Pliocene land. I would merely remark, in addition to the considerations already advanced, that the occurrence of drift-wood in the Erie clay, and of sea shells in the Boulder-clay, are both most serious objections to the glacier hypothesis, reserving for the sequel a more full discussion of the rival theories.

While the marginal marine area strictly corresponds to the marginal areas of Europe, I have no distinct evidence that the internal plains and table lands of the old continent correspond in their formations to the internal lake area of America.

An interesting fact with reference to the Erie clay, stated in the Report of the Survey of Canada is, that these clays burn into

white brick, while the marine Leda clay burns into red brick. The chemical cause of this I have already referred to, but whether it implies that the inland clays are fresh-water, or only that they have been derived from a different material, is uncertain. The gray clays of the Hudson River series in Western Canada, might, according to Mr. Bell, have afforded such clays.

Under the theory of a glacial sea immediately succeeding the elevated Pliocene land, the great amount of decomposed rocks which must have accumulated upon the latter constitutes an important element in the estimation of the rate of deposit of the Erie and Boulder and Leda clays. It is also to be observed that this glacial sea might have had to scour out of the lake basins of Canada only the soft mud of its own deposition, the rock-excavation having apparently been in great part effected in the previous Pliocene period. On this subject I find that Dr. Sterry Hunt had, before the publication of Dr. Newberry already alluded to,* shown that not only channels but considerable areas about Lakes Erie and St. Clair had been deeply excavated in the palæozoic rocks and filled with Post-pliocene deposits. The Devonian strata, he remarks, "are found in the region under consideration at depths not only far beneath the water level of the adjacent Lakes Erie and St. Clair, but actually below the horizon of the bottom of these shallow lakes." He shows that around these in various localities the solid rocks are only met with at depths of from one to two hundred feet below the level of the lakes, while "the greatest depth of Lake St. Clair is scarcely thirty feet and that of the South-western half of Lake Erie does not exceed sixty or seventy feet, so that it would seem that these present lake basins have been excavated from the Post-pliocene clays, which, in this region, fill a great ancient basin previously hollowed out of the palæozoic rocks, and including in its area the South-western part of the peninsula of Ontario."

It would thus appear that in the Pliocene period the basin of the lakes may have been a great plain with free drainage to the sea. Whether or not it was afterwards occupied by a glacier, this plain and its channels leading to the ocean were filled with clay at the beginning of the Post-pliocene subsidence; and at a later date the mud was again swept out from those places where the Arctic current could most powerfully act on it.

* On the Geology of South-western Ontario. Am. Jour. Sci. 1868

Roches Moutonneés – Mouth of the Saguenay.
In Gneiss, at Elevation of 300 Feet.

Clay & Sand Terraces – Tadousac

A.L.D. del.

LEGGO & Cº Lith Montreal.

PART II.—LOCAL DETAILS.

Before entering into the special consideration of this Second Part of the subject, I desire to call attention to some additional facts bearing on two of the most remarkable properties of the Post-pliocene deposits of the Northern Hemisphere, namely their general similarity of arrangement, and their local diversities.

In the first part of this memoir, taking the Post-pliocene of the Lower St. Lawrence as a type, I showed that it has its parallel, with but slight general difference, in the wide-spread superficial deposits of the interior of North America surrounding the great lakes, and that the Post-pliocene deposits of Scotland and Scandinavia almost precisely resemble those of Canada in the general sequence of deposits. Since that part was published, additional illustrations have been afforded by papers in the Geological Magazine by Mr. Hull, and Mr. Mackintosh, by papers and discussions on the Eskers of Ireland, at the meeting of the British Association, and by an able monograph on the Estuary of the Forth, by Mr. David Milne Home. Mr. Hull, who is a "Land Glacialist," arranges the deposits of the Drift Period in the British area in the following three groups, in descending order, in accordance with Prof. Ramsay's observations in England, and his own in Ireland.

1. Upper Boulder-clay, which he regards as "generally marine." In Canada, this is represented by the loose boulders and partial boulder deposits of the Upper Saxicava Sand.

2. Shelly marine sands and gravels belonging to the greatest depression of the land, and representing our Saxicava Sand and Leda Clay.

3. Lower Boulder-clay, which represents the true or principal Boulder-clay of Canada. This Mr. Hull attributes "chiefly to land ice."

In Ireland, it would thus seem that the principal sub-divisions of the Post-pliocene can be recognized, and Mr. Kinahan has described the remarkable ridges of gravel called eskers which run

across the country in a North-east and South-west direction, Like our Canadian eskers or "Boar's backs," they are now admitted to be of marine origin, and are attributed to current action and to the waves, though floating ice has no doubt, as in Canada, contributed in some cases to their formation.

Mr. Milne Home gives a graphic description of the Post-pliocene deposits in the neighbourhood of the Frith of Forth, and many of his numerous sections might have just as well been taken from Canadian deposits. He thus sums up the causes of the phenomena, assuming that at the beginning of the period the land was submerged.

"The ocean over and around Scotland was full of icebergs and shore ice, which spread fragments of rocks over the sea bottom and often stranded, ploughing through beds of mud, sand, gravel, and blocks of stone, and mingling them together in such a way as to form the 'Boulder-clay.' The land thereafter gradually emerged, during which time the long ridges or embankments of gravel called 'kames' were formed."

Mr. Mackintosh's observations go mainly to show that in England, as in Canada, even the lower drift and rock striation are due to a great extent to floating ice and not to glaciers, and he extends this conclusion even into the lake district of England.

It is also worthy of remark that the long-received doctrine that glaciers are powerful eroding agents, which the author showed in a paper in this journal, in 1866, to be without foundation, is only now beginning to be discredited in England. I shall refer to this in the sequel, and in the meantime may direct attention to an interesting paper on the subject by Mr. Bonney, F.G.S., in the Journal of the Geological Society for August, 1871.

It would further appear that, after the glacial period, in the Post-glacial, the British land rose to a level higher than that which it at present exhibits, then sunk again, and re-emerged in the modern period. Evidences of this later submergence have not been recognized in Canada, but in the inland area they have been detected by Hilgard and by Andrews.

Since the publication of the first part of this memoir, Prof. Hilgard has discussed the subject of the southern drifts of the Mississippi valley at the meeting of the American Association at Indianapolis; and I am indebted to that gentleman and to Prof. Andrews, of Chicago, for much information on these deposits and their relation to those of more northern regions.

It appears that the oldest Post-pliocene deposit in the south is that called by Prof. Hilgard the "Orange Sand." This deposit is spread over the States of Mississippi, Alabama, Tennessee, and parts of Louisiana, Kentucky, and Arkansas, and in some places attains an elevation of 700 feet. It contains water-worn fragments of northern rocks, and is supposed by Prof. Hilgard to have been deposited by rapid currents of water, possibly fresh, as the deposit contains no marine fossils.

Above this, according to Prof. Hilgard, is found in places a swamp, lagoon or estuary formation designated the "Port Hudson group." Succeeding this is the "Bluff or Loess" group, a deposit of fine silt, limited almost or entirely to the Valley of the Mississippi. Its maximum thickness is seventy-five feet.

On this rests a very widely distributed bed, the "Yellow Loam," not more than twenty feet thick, but much more extensively distributed laterally than the former, and reaching an elevation of 700 feet.

Under the names of "Second Bottoms or Hummocks," and "First Bottoms," are known terraced deposits of clay belonging to the present river valleys, but indicating in the case of the Second Bottoms a greater amount of water than at present.

It is obvious that all of the above are aqueous deposits, and there seems to be no evidence whatever in the region referred to, of the action of land ice, though the stones and few boulders in the Orange sand are very probably due to floating ice. There seems reason to believe that the Orange sand is continuous with the Boulder-drift of the north-west; and if this is, as stated by Newberry and others, a later deposit than the Erie clay, then it is probable that no representative of the latter exists to the south-west, or that the Orange sand represents the whole of the northern deposits. In any case it represents northern currents of water, though whether salt water admitted by the depression of the land, or fresh water resulting from the melting of glaciers, it is not easy to decide, as very great difficulties attend either view in the present state of our knowledge of the deposit. Whatever the conditions of deposit of the Orange sand, it would seem to have been succeeded by a land surface, and this by a depression to the extent of 700 feet or more, before the modern elevation of the land. If this last elevation corresponds with that of the terraces of the St. Lawrence, then the former one must have occurred in the St. Lawrence valley in the interval

between the deposit of the Leda clay and the close of the Post-pliocene. This question we shall have occasion to consider in the sequel, in connection with the second depression of the European land above referred to.

Since the publication of the first of these papers, Dr. Newberry has kindly sent me a paper of his published as early as 1862, in which he states the remarkable fact, quoted above from his more recent Report on Ohio, that the drainage of the great lake basins, open in the early Post-pliocene period, was obstructed by the glacial deposits, and has been only partially restored. He also desires me to state that he refers the old drainage not exclusively to the action of glaciers, but to the "ice period, or an earlier epoch." I am happy to make these corrections; the latter more especially, as it brings our theoretical views more into harmony. Dr. Newberry, however, for whose conclusions on such subjects I have the highest respect, still, in his latest expressions of opinion, adheres to the action of land ice in producing the glacial striation, which from his descriptions is, I should suppose, quite as definite and strongly marked as that in the St. Lawrence valley.

The grand series of Post-pliocene changes was thus uniform in Europe and America, pointing to great general causes of subsidence and re-elevation; but locally there is the most extreme irregularity in these deposits, giving great uncertainty to their arrangement. Some of these differences we shall have occasion to notice under the following geographical subdivisions.

1. *Newfoundland and Labrador.*

In the Journal of the Geological Society of London, for February, 1871, is a communication from Staff-commander Kerr, R. N., of the Coast Survey, in which he gives the directions of twenty-eight examples of grooved and scratched surfaces observed in the southern part of Newfoundland. The course of the majority of these is N.E. and S.W., ranging from N.8° E. to N. 64° E. The remainder are N.W. and S.E., most of them with a predominating Easterly direction. Boulders are mentioned, but no marine beds. The author refers the glaciation to land ice, supposing certain submerged banks across the mouths of the bays to be terminal moraines.

The latest information on the Post-pliocene of Labrador is that given in a paper by Dr. Packard in the memoirs of the Boston Society

of Natural History for 1867. The deposits are said to consist of boulders, Leda clay and sand, and raised beaches, which, on the authority of Prof. Hind, are stated to reach an elevation of 1200 feet above the sea. The hills to a height of 2500 feet are rounded as if by ice action. Some higher hills present a frost-shattered surface at their summits. No directions of striæ are given, and they appear to be rare. Mr. Campbell, author of "Frost and Fire," mentions examples with course N. 45° E. in the Strait of Belle Isle. It is remarkable that true Boulder-clay is rare in Labrador, though loose boulders are abundant in the valleys and on the inland table land. Dr. Packard attributes the absence of Boulder-clay to denudation. This may be the cause, but it is to be observed that, on that view of the origin of Boulder-clay which attributes it to ice-laden arctic currents, there must always have been in the course of such currents areas of denudation as well as areas of deposition, and an elevated table-land like that of Labrador, in a high northern latitude, may well have been of the former character.

The Leda clay occurs in several places. In 1860, I published a list of species collected by Capt. Orlebar; and Packard has greatly added to the number, giving a list which will be referred to farther on. Dr. Packard very truly remarks that the fauna of the Labrador clays is very similar to that now found on the coast, and called by him the Syrtensian fauna. In the latter we have a few southern forms, absent in the clay, but this is all. Further, the Labrador Post-pliocene fauna is identical or nearly so with that of similar deposits in South Greenland, described by Möller and Rink. Thus the climatal conditions of the arctic current on the coast of Labrador seem to have in no respect differed in the Post-pliocene from those which obtain at present. The Leda clay with its characteristic fossils is found as high as 500 feet above the level of the sea.

Raised beaches and terraces, whether cut into sand and clay or the hard metamorphic rocks of the coast, are as common in Labrador as along the shores of the River St. Lawrence. Their precise altitudes are not given, but they appear to be very numerous and to rise to a great height above the sea. One feature of some interest is their consisting in some places of large stones and boulders, evidencing very powerful action of coast ice and currents. Packard speaks of many of these beaches as moraines modified by the sea, but he gives no reason for this except the general

belief that extensive glaciers existed in Labrador in the Post-pliocene, of which, however, there seems little direct evidence. From the descriptions of Prof. Hind,* however, it would seem that traces of local glaciers in the river valleys, similar to those referred to above in the case of the Saguenay and the Murray River, exist, and these might now be restored by a slight increase of cold and a moderate elevation of the land.

On the island of Anticosti, Messrs. Hyatt, Verrill and Shaler found *Saxicava arctica* in clay at an elevation of fifteen feet above the level of the sea.

Before proceeding up the St. Lawrence Valley into Canada proper, I may cross to the south side of the Gulf of St. Lawrence and notice the drift deposits of Prince Edward Island, Nova Scotia and New Brunswick, and their connection with those of the State of Maine.

2. *Prince Edward Island.*

The Triassic and Upper Carboniferous rocks of this island consist almost entirely of red sandstones, and the country is low and undulating, its highest eminences not exceeding 400 feet. The prevalent Post-pliocene deposit is a Boulder-clay, or in some places boulder loam, composed of red sand and clay derived from the waste of the red sandstones. This is filled with boulders of red sandstone derived from the harder beds. They are more or less rounded, often glaciated, with striæ in the direction of their longer axis, and sometimes polished in a remarkable manner, when the softness and coarse character of the rock are considered. This polishing must have been effected by rubbing with the sand and loam in which they are embedded. These boulders are not usually large, though some were seen as much as five feet in length. The boulders in this deposit are almost universally of the native rock, and must have been produced by the grinding of ice on the outcrops of the harder beds. In the eastern and middle portion of the Island, only these native rocks were seen in the clay, with the exception of pebbles of quartzite which may have been derived from the Triassic conglomerates. At Campbellton, in the western part of the Island, I observed a bed of Boulder-clay filled with boulders of metamorphic rocks similar to those of the mainland of New Brunswick.

* Trans. Geol. Society, 1864.

Striæ were seen only in one place on the North-eastern coast and at another on the South-western. In the former case their direction was nearly S.W. and N.E. In the latter it was S. 70° E.

No marine remains were observed in the Boulder-clay; but at Campbellton, above the Boulder-clay already mentioned, there is a limited area occupied with beds of stratified sand and gravel, at an elevation of about fifty feet above the sea, and in one of the beds there are shells of *Tellina Grœnlandica*.

On the surface of the country, more especially in the western part of the island, there are numerous travelled boulders, sometimes of considerable size. As these do not appear in situ in the Boulder-clay, they may be supposed to belong to a second or newer boulder drift similar to that which we shall find to be connected with the Saxicava sand in Canada. These boulders being of rocks foreign to Prince Edward Island, the question of their source becomes an interesting one. With reference to this, it may be stated in general terms, that the majority are Granite, Syenite, Diorite, Felsite, Porphyry, Quartzite and coarse slates, all identical in mineral character with those which occur in the metamorphic districts of Nova Scotia and New Brunswick, at distances of from 50 to 200 miles to the South and South-west; though some of them may have been derived from Cape Breton on the East. It is further to be observed that these boulders are most abundant and the evidences of denudation of the Trias greatest in that part of the Island which is opposite the deep break between the hills of Nova Scotia and New Brunswick, occupied by the Bay of Fundy, Chiegnecto Bay and the low country extending thence to Northumberland Strait, an evidence that this boulder drift was connected with currents of water passing up this depression from the South or South-west.

Besides these boulders, however, there are others of a different character; such as Gneiss, Hornblende schist, Anorthosite and Labradorite rock, which must have been derived from the Laurentian rocks of Labrador and Canada, distant 250 miles or more, to the Northward. These Laurentian rocks are chiefly found on the North side of the island, as if at the time of their arrival the island formed a shoal, at the North side of which the ice carrying the boulders grounded and melted away. With reference to these boulders, it is to be observed that a depression of four or five hundred feet would open a clear passage for the arctic current entering the Straits of Belle Isle, to-

the Bay of Fundy; and that heavy ice carried by this current would then ground on Prince Edward Island, or be carried across it to the Southward. If the Laurentian boulders came in this way, their source is probably 400 miles distant in the Strait of Belle Isle. On the North shore of Prince Edward Island, except where occupied by sand dunes, the beach shows great numbers of pebbles and small boulders of Laurentian rocks. These are said by the inhabitants to be cast up by the sea or pushed up by the ice in spring. Whether they are now being drifted by ice direct from the Labrador coast, or are old drift being washed up from the bottom of the gulf, which north of the island is very shallow, does not appear. They are all much rounded by the waves, differing in this respect from the majority of the boulders found inland.

The older Boulder-clay of Prince Edward Island, with native boulders, must have been produced under circumstances of powerful ice-action, in which comparatively little transport of material from a distance occurred. If we attribute this to a glacier, then as Prince Edward Island is merely a slightly raised portion of the bottom of the Gulf of St. Lawrence, this can have been no other than a gigantic mass of ice filling the whole basin of the gulf, and without any slope to give it movement except toward the centre of this great though shallow depression. On the other hand, if we attribute the Boulder-clay to floating ice, it must have been produced at a time when numerous heavy bergs were disengaged from what of Labrador was above water, and when this was too thoroughly enveloped in snow and ice to afford many travelled stones. Farther, that this Boulder-clay is a submarine and not a subaerial deposit, seems to be rendered probable by the circumstance that many of the boulders of sandstone are so soft that they crumble immediately when exposed to the weather and frost.

The travelled boulders lying on the surface of the Boulder-clay evidently belong to a later period, when the hills of Labrador and Nova Scotia were above water, though lower than at present, and were sufficiently bare to furnish large supplies of stones to coast ice carried by the tidal currents sweeping up the coast, or by the Arctic current from the North, and deposited on the surface of Prince Edward Island, then a shallow sand-bank. The sands with sea-shells probably belonged to this period, or perhaps to the later part of it, when the land was gradually rising. Prince

Edward Island thus appears to have received boulders from both sides of the gulf of St. Lawrence during the later Post-pliocene period; but the greater number from the South side, perhaps because nearer to it. It thus furnishes a remarkable illustration of the transport of travelled stones at this period in different directions, and in the comparative absence of travelled stones in the lower Boulder-clay, it furnishes a similar illustration of the homogeneous and untravelled character of that deposit, in circumstances where the theory of floating ice serves to account for it, at least as well as that of land-ice, and in my judgment greatly better.

3. *Nova Scotia and New Brunswick.*

In these Provinces the circumstances are entirely different from those in Prince Edward Island, the country consisting of Carboniferous and Triassic plains, with ranges of older hills, often metamorphic, and attaining elevations of 1200 feet or more. It may, perhaps, be best in the first instance to present a summary of the phenomena, as I have given them in my Acadian Geology, and to add such additional facts and inferences as the present state of the subject may require.

The beds observed may be arranged as follows, in descending order.

1. Gravel and sand beds, and ancient gravel ridges and beaches, indicating the action of shallow water, and strong currents and waves. Travelled boulders occur in connection with these beds.
2. Stratified clay with shells, showing quiet deposition in deeper water.
3. Unstratified Boulder-clay, indicating, probably, the united action of ice and water.
4. Peaty deposits, belonging to a land surface preceding the deposit of the Boulder-clay.

As the third of these formations is the most important and generally diffused in Nova Scotia and New Brunswick, we shall attend to it first, and notice the relation of the others to it.

The Unstratified Drift or Boulder-clay varies from a stiff clay to loose sand, and its composition and colour generally depend upon those of the underlying and neighbouring rocks. Thus, over sandstone it is arenaceous, over shales argillaceous, and over conglomerates and hard slates pebbly or shingly. The greater

number of the stones contained in the drift are usually, like the paste containing them, derived from the neighbouring rock formations. These untravelled fragments are often of large size, and are usually angular, except when they are of very soft material, or of rocks whose corners readily weather away. It is easy to observe, that on passing from a granite district to one composed of slate, or from slate to sandstone, the character of the loose stones changes accordingly. It is also a matter of familiar observation, that in proportion to the hardness or softness of the prevailing rocks, the quantity of these loose stones increases or diminishes. In some of the quartzite and granite districts of the Atlantic coast, the surface seems to be heaped with boulders with only a little soil in their interstices, and every little field, cleared with immense labour, is still half-filled with huge white masses popularly known as "elephants." On the other hand, in the districts of soft sandstone and shale, one may travel some distance without seeing a boulder of considerable size. The boulders are as usual often glaciated or marked with ice-striæ.

Though the more abundant fragments are untravelled, it by no means follows that they are undisturbed. They have been lifted from their original beds, heaped upon each other in every variety of position, and intermixed with sand and clay, in a manner which shows convincingly that the sorting action of running water had nothing to do with the matter; and this applies not only to stones of moderate size, but to masses of ten feet or more in diameter. In some of the carboniferous districts where the Boulder-clay is thick, as for example, near Pictou Harbour, it is as if a gigantic harrow had been dragged over the surface, tearing up the outcrops of the beds, and mingling their fragments in a rude and unsorted mass.

Besides the untravelled fragments, the drift always contains boulders derived from distant localities, to which in many cases we can trace them; and I may mention a few instances of this to show how extensive has been this transport of detritus. In the low country of Cumberland there are few boulders, but of the few that appear some belong to the hard rocks of the Cobequid hills to the Southward; others may have been derived from the somewhat similar hills of New Brunswick. On the summits of the Cobequid hills and their Northern slopes, we find angular fragments of the sandstones of the plain below, not only drifted from their original sites, but elevated several hundreds of feet

above them. To the Southward and Eastward of the Cobequids, throughout Colchester, Northern Hants, and Pictou, fragments from these hills, usually much rounded, are the most abundant travelled boulders, showing that there has been great driftage from this elevated tract. Near the town of Pictou, where a thick bed of a sandy boulder deposit occurs, this is filled with large masses of sandstone derived from the outcrops of the beds on higher ground to the north; but with these are groups of travelled stones often in the lower part of the mass. Near the steam ferry wharf, in the town of Pictou, I observed one such group, consisting of the following, all large boulders and lying close together—two of red syenite, six of gray granite, one of compact grey felsite, one of hard conglomerate, two of hard grit. The two last were probably Lower Carboniferous, the others derived from the altered Silurian deposits. All may have been drifted by one berg or ice-floe from the flanks of the Cobequid range of hills. In like manner, the long ridge of trap rocks, extending from Cape Blomidon to Briar Island, has sent off great quantities of boulders across the sandstone valley which bounds it on the South and up the slopes of the slate and granite hills to the Southward of this valley. Well characterized fragments of trap from Blomidon may be seen near the town of Windsor; and I have seen unmistakeable fragments of similar rock from Digby neck, on the Tusket River, thirty miles from their original position. On the other hand, numerous boulders of granite have been carried to the Northward from the hills of Annapolis, and deposited on the slopes of the opposite trappean ridge; and some of them have been carried round its Eastern end, and now lie on the shores of Londonderry and Onslow. So also, while immense numbers of boulders have been scattered over the South coast from the granite and quartz rock ridges immediately inland, many have drifted in the opposite direction, and may be found scattered over the counties of Antigonish, Pictou, and Colchester. These facts show that the transport of travelled blocks, though it may here as in other parts of America, have been principally from the Northward, has by no means been exclusively so; boulders having been carried in various directions, and more especially from the more elevated and rocky districts to the lower grounds in their vicinity. Professor Hind has shown the existence of a similar relation between the boulders of New Brunswick and the hilly ranges of that country.

The following are the directions of the diluvial scratches in a number of localities in different parts of Nova Scotia :—

Point Pleasant and other places near Halifax, exposure south, very distinct striæ, . . .	S. 20° E. to S. 30° E.
Head of the Basin, exposure south, but in a valley, . . .	E. & W. nearly.
La Have River, exposure S.E., .	S. 20° W.
Petite River, exposure S. . .	S. 20° E.
Bear River, exposure N., .	S. 30° E.
Rawdon, exposure N., . .	S. 25° E.
The Gore Mountain, exposure N., two sets of striæ, respectively, .	S. 65° E. & S. 20° E.
Windsor Road, exposure not noted,	S.S.E.
Gay's River, exposure N., .	Nearly S. & N.
Musquodoboit Harbour, exposure S.,	Nearly S. & N.
Near Pictou, exposure E., in a valley,	Nearly E. & W.
Polson's Lake, summit of a ridge, .	Nearly N. & S.
Near Guysboro', exposure not noted,	Nearly S. & N.
Sydney Mines, Cape Breton, exposure S	S. 30° W.*

The above instances show a tendency to a Southerly and South-easterly direction, which accords with the prevailing course in most parts of North-eastern America. Local circumstances have, however, modified this prevailing direction; and it is interesting to observe that, while S.E. is the prevailing direction in Acadia and New England, it is exceptional in the St. Lawrence valley, where the prevailing direction is S.W. Professor Hind has given a table of similar striation in New Brunswick, showing that the direction ranges from N. 10° W. to N. 30° E., in all except a very few cases. On Blue Mountains, 1650 feet above the sea, it is stated to be N. and S. As in Nova Scotia, N. W. and S. E. seems to be the prevailing course. In a paper published in the Canadian Naturalist, Vol. VI., No. 1, Mr. Matthew gives a table of striation in the southern part of New Brunswick, in which the South-east direction is decidedly predominant, though there are also some in the South west direction. In this paper will also be found many interesting facts as to the Boulder-clay of New Bruns-

* The above courses are *magnetic*, the average variation being about 18° W.

wick, though the agency of a continental glacier is invoked to explain some facts which in the sequel we shall find to admit of a different interpretation.

The travelled and untravelled boulders are usually intermixed in the drift. In some instances, however, the former appear to be most numerous near the surface of the mass, and their horizontal distribution is also very irregular. In examining coast sections of the drift, we may find for some distance a great abundance of angular blocks, with few travelled boulders, or both varieties are equally intermixed, or travelled boulders prevail; and we may often observe particular kinds of these last grouped together, as, for instance, a number of blocks of granite, greenstone, syenite, etc., all lying together, as if they had been removed from their original beds and all deposited together at one operation. On the surface of the country where the woods have been removed, this arrangement is sometimes equally evident; thus hundreds of granite boulders may be seen to cumber one limited spot, while in its neighbourhood they are comparatively rare. It is also well known to the farmers in the more rocky districts, that many spots which appear to be covered with boulders have, when these are removed, a layer of soil comparatively free from stones beneath. These appearances may in some instances result from the action of currents of water, which have in spots carried off the sand or clay, leaving the boulders behind; but in many cases this is manifestly the original arrangement of the material, the superficial layer of boulders belonging to a more recent driftage than that of the underlying mass in which boulders are often much less abundant.

Boulders or travelled stones are often found in places where there is no other drift. For example, on bare granite hills, about 500 feet in height, near St. Mary's River, there are large angular blocks of quartzite, derived from the ridges of that material which abound in the district, but which are separated from the hills on which the fragments lie by deep valleys.

In Nova Scotia I have observed no beds with marine shells, though the Boulder-clay is often covered with beds of stratified sand and gravel; and the only evidence of organic life, during the boulder period, or immediately before it, that I have noticed, is a hardened peaty bed which appears under the Boulder-clay on the North-west arm of the River of Inhabitants in Cape Breton. It rests upon gray clay similar to that which underlies peat bogs,

and is overlaid by nearly twenty feet of Boulder-clay. Pressure has rendered it nearly as hard as coal, though it is somewhat tougher and more earthy than good coal. It has a shining streak, burns with considerable flame, and approaches in its characters to the brown coals or more imperfect varieties of bituminous coal It contains many small roots and branches, apparently of coniferous trees allied to the spruces. The vegetable matter composing this bed must have flourished before the drift was spread over the surface.

In New Brunswick, stratified clays holding marine shells have been found overlying the Boulder-clay, or in connexion with it, especially in the Southern part of the Province, where deposits of this kind occur similar to those found in Canada and in Maine, though apparently on a smaller scale. These deposits, as they occur near St. John, consist of gray and reddish clays, holding fossils which indicate moderately deep water, and are, as to species, identical with those occurring in similar deposits in Canada and in Maine. They would indicate a somewhat lower temperature than that of the waters of the Bay of Fundy at present, or about that of the Northern part of the Gulf of St. Lawrence.

In Bailey's Report on the Geology of Southern New Brunswick, Professor Hartt has given a list of the fossils of these beds, as seen at Lawlor's Lake, Duck Cove, and St. John, which I republished with some additions in Acadian Geology.

These New Brunswick beds are strictly continuous with, and equivalent to those which extend along the coast of New England, and thence ascend into the Valley of Lake Champlain, while on the other side they may be considered as perfectly representing in character and fossils the Leda clay of Eastern Canada. They are remarkably like both in mineral character and fossils to the Clyde beds of Scotland, which are probably their equivalents. The points of resemblance of the Leda clay of the coast of Maine, and that of the St. Lawrence, and Labrador, were noticed by me in my paper of 1860, already referred to, and have been more fully brought out by Dr. Packard, who describes the Leda clay as it occurs at several localities from Eastport to Cape Cod. Along this whole coast it retains its Labradoric or Gulf of St. Lawrence aspect, though with the introduction of some more Southern species, and the gradual failure of some more arctic forms. South of Cape Cod, as in the modern sea, the Post-pliocene beds assume a much more Southern aspect in their fossils,

the boreal forms altogether disappearing. For a very full exhibition of these facts, I may refer to Dr. Packard's paper.

The stratified sand and gravel of Nova Scotia rests upon and is newer than the Boulder-clay, and is also newer than the stratified marine clays above referred to. Its age is probably that of the Saxicava Sand of the St. Lawrence valley. The former relation may often be seen in coast sections or river banks, and occasionally in road cuttings. I observed some years ago an instructive illustration of this fact, in a bank on the shore a little to the Eastward of Merigomish harbour. At this place the lower part of the bank consists of clay and sand with angular stones, principally sandstones. Upon this rests a bed of fine sand and small rounded gravel with layers of coarser pebbles. The gravel is separated from the drift below by a layer of the same sort of angular stones that appear in the drift, showing that the currents which deposited the upper bed have washed away some of the finer portions of the drift before the sand and gravel were thrown down. In this section, as well as in most others that I have examined, the lower part of the stratified gravel is finer than the upper part, and contains more sand.

In some cases we can trace the pebbles of the gravels to ancient conglomerate rocks which have furnished them by their decay; but in other instances the pebbles may have been rounded by the waters that deposited them in their present place. In places, however, where old pebble rocks do not occur, we sometimes find, instead of gravel, beds of fine laminated sand. A very remarkable instance of the connexion of superficial gravels with ancient pebble rocks occurs in the county of Pictou. In the coal formation of this county there occurs a very thick bed of conglomerate, the outcrop of which, owing to its comparative hardness and great mass, forms a high ridge extending from the hill behind New Glasgow across the East and Middle Rivers, and along the South of the West River, and then, crossing the West River, re-appears in Rogers' Hill. The valleys of these three rivers have been cut through this bed, and the material thus removed has been heaped up in hillocks and beds of gravel, along the banks of the streams, on the side toward which the water now flows, which happens to be the North and North-east. Accordingly, along the course of the Albion Mines Railway and the lower parts of the Middle and West Rivers, these gravel beds are everywhere exposed in the road-cuttings, and may in some places be seen to rest on

the Boulder-clay, showing that the cutting of these valleys was completed after the drift was produced. Similar instances of the connexion of gravel with conglomerate occur near Antigonish, and on the sides of the Cobequid mountains, where some of the valleys have at their Southern entrances immense tongues of gravel extending out into the plain, as if currents of enormous volume had swept through them from North to South.

The stratified gravels do not, like the older drift, form a continuous sheet spreading over the surface. They occur in mounds and long ridges, or eskers, sometimes extending for miles over the country. One of the most remarkable of these ridges is the "Boar's Back," which runs along the West side of the Hebert River in Cumberland. It is a narrow ridge, perhaps from ten to twenty feet in height, and cut across in several places by the channels of small brooks. The ground on either side appears low and flat. For eight miles it forms a natural road, rough indeed, but practicable with care to a carriage, the general direction being nearly North and South. What its extent or course may be beyond the points where the road enters on and leaves it, I do not know; but it appears to extend from the base of the Cobequid mountains to a ridge of sandstone that crosses the lower part of the Hebert river. It consists of gravel and sand, whether stratified or not I could not ascertain, with a few large boulders. Another very singular ridge of this kind is that running along the West side of Clyde river in Shelburne county. This ridge is higher than that on Hebert river, but, like it, extends parallel to the river, and forms a natural road, improved by art in such a manner as to be a very tolerable highway. Along a great part of its course it is separated from the river by a low alluvial flat, and on the land side a swamp intervenes between it and the higher ground. Shorter and more interrupted ridges of this kind may also be seen in the country Northward and Eastward of the town of Pictou. In sections they are seen to be stratified, and they generally occur on low or level tracts, and in places where if the country were submerged, the surf or marine currents and tides might be expected to throw up ridges. The presence of boulders shows that ice grounded on these ridges, and it, probably by its pressure, in some instances, modified their forms. These eskers, or "horse-backs," must not, however, be confounded with glacier moraines, to which in structure they bear no resemblance whatever.

It is probably to this more modern part of the Post-pliocene, if not to a more recent period following the elevation of the land, that the bones of the mastodon found in Cape Breton, and described in "Acadian Geology," belong.

For many additional facts relating to the Post-pliocene of New Brunswick, I may refer to the valuable paper by Mr. Matthew, already mentioned.

4. *Lower St. Lawrence—North Side.*

Descriptions of the Post-pliocene deposits of this region are contained in several of my papers above cited, but I shall here give a summary of these, with the corrections and additional facts obtained within the past few years.

Saguenay River.—I have already, in part first, referred to the glacial striation of this region, and perhaps no better example could be found of those lateral valleys along which ice seems to have been poured into the St. Lawrence from the North. The gorge of the Saguenay is a narrow and deep cut, running nearly N.W. and S.E., or at right angles to the course of the St. Lawrence, and of the Laurentian ridges. It extends inland more than forty-five miles, and then divides into two branches, one of which is occupied by the continuation of the river to Lake St. John, the other by Ha-Ha Bay and a valley at its head. In the lower part of its course, as far as Ha-Ha Bay, this gorge is from 50 to 140 fathoms deep, below the level of the tide in the St. Lawrence, and in some places the cliffs on its banks rise abruptly to 1500 feet above the water level, so that its extreme depth is nearly 2400 feet, while its width varies from about a mile to a mile and a-half. The striated surfaces and the roches moutonnées seen in this gorge and on the hills on its sides, to a height of at least 300 feet, shew that in the glacial period a powerful stream of ice must have flowed down this gorge into the St. Lawrence, though whether it was occupied by a glacier or constituted a fiord leading from one, like many in Greenland, or was a strait traversed by bergs, does not appear. Possibly, with different levels of the land, these conditions may have alternated. I cannot imagine anything more like what the Saguenay may have been at this time, than the view of Franz Joseph Fiord in East Greenland, brought home by the second German expedition to that country, in the present year,* and which, with other discoveries of that

* Copied in the "Leisure Hour" for November, 1871.

expedition soon to be published by Dr. Petermann, will go far to remove the prevailing error as to Greenland being covered with a universal glacier; whereas it seems to be a rocky and mostly snow-clad country, with very large glaciers in its valleys.

The strikes of the gneiss on the opposite sides of the Saguenay indicate that it occupies a line of transverse fracture, constituting a weak portion of the Laurentian ridges, and this has evidently been smoothed and deepened by water and ice under conditions different from the present, in which it is probable that the channel is being gradually filled with mud. Its excavation must have taken place before the deposition of the thick beds of marine clay (Leda clay) which appear near its mouth and in its tributaries, sometimes passing into Boulder-clay below, and capped by sand and gravel. It is indeed not improbable that in the later Post-pliocene it was in great part filled up with such deposits, which have been swept away in the course of the re-elevation of the land.

At Tadoussac, at the mouth of the Saguenay, where the underlying formation is the Laurentian gneiss, the Post-pliocene beds attain to great thickness, but are of simple structure and slightly fossiliferous. The principal part is a stratified sandy clay with few boulders, except in places near the ridges of Laurentian rocks, when it becomes filled with numerous rounded blocks and pebbles of gneiss. This forms high banks eastward of Tadoussac. It contains a few shells of *Tellina Grœnlandica* and *Leda truncata*, and a little inland, at Bergeron River, it also contains *Cardium Islandicum*, *Astarte elliptica*, and *Rhynchonella psittacea*. It resembles some of the beds seen on the South side of the river St. Lawrence, and has also much of the aspect of the Leda clay, as developed in the valley of the Ottawa. On this clay there rest in places thick beds of yellow sand and gravel.

At Tadoussac these deposits have been cut into a succession of terraces which are well seen near the hotel and old church. The lowest, near the shore, is about ten feet high; the second, on which the hotel stands, is forty feet; the third is 120 to 150 feet in height, and is uneven at top. The highest, which consists of sand and gravel, is about 250 feet in height. Above this the country inland consists of bare Laurentian rocks. These terraces have been cut out of deposits, once more extensive, in the process of elevation of the land; and the present flats off the mouth of the Saguenay, would form a similar terrace as wide as any of the others, if the country were to experience another elevatory move-

ment. On the third terrace I observed a few large Laurentian boulders, and some pieces of red and gray shale of the Quebec group, indicating the action of coast-ice when this terrace was cut. On the highest terrace there were also a few boulders; and both terraces are capped with pebbly sand and well rounded gravel, indicating the long-continued action of the waves at the levels which they represent.

Murray Bay, &c.—At Murray Bay, Petit Mal Bay, and Les Eboulements, as noticed above, the system of Post-pliocene terraces is well developed. On the West side of Murray Bay, the Silurian rocks of White Point, immediately within the pier, form a steep cliff, in the middle of which is a terraced step marking an ancient sea level. At the end nearest the pier the sea has again cut back to the old cliff, leaving merely a narrow shelf; but toward the inner side this shelf rapidly expands into the sandy flat along which the main road runs, and which is continuous with the lower plain extending all the way to the head of the bay. In this flat the upper portion of the Post-pliocene deposit seems to consist principally of sand and gravel, resting on stony clay. In the former, which corresponds to the Saxicava sand of Montreal, I found only a few valves of *Tellica Grœnlandica* which is still the most abundant shell on the modern beach. In the latter, corresponding to the Leda clay, which is best seen in some parts of the shore at low tide, I found a number of deep water shells of the following species, all of which, except *Spirorbis spirillum* and *Aphrodite Grœnlandica*, have been found in these deposits at Quebec and Montreal.

Fusus tornatus.
Trophon Scalariforme.
Margarita helicina.
Cylichna occulta.
Pecten Islandicus.
Tellina calcarea.
Leda truncata.
Saxicava rugosa.
Aphrodite Grœnlandica.
Mytilus edulis.
Mya arenaria.
Balanus Hameri.
Spirorbis spirillum.
S. vitrea.
Serpula vermicularis.

These shells imply a higher beach than that of this lower flat, which is not more than 30 feet above the present sea level. Accordingly above this are several higher terraces, the heights of which on the west side of bay are given in Section I. The second principal terrace, which forms a steep bank of clay some distance behind the main road, is 116 feet in height, and is of considerable breadth, and has on its front in some places an imperfect terrace at the height of 81 feet. It corresponds nearly in height with the shoulder over which the road from the pier passes. Upon it, in the rear of the property of Mr. Du Berger, is a little stream which disappears under ground, probably in a fissure of the underlying limestone, and returns to the surface only on the shore of the bay. Above this is a smaller and less distinct terrace 139 feet high. Beyond this the ground rises in a steep slope, which in many places consists of calcareous beds, worn and abraded by the waves, but showing no distinct terrace; and the highest distinct shore mark which I observed, is a narrow beach of rounded pebbles at the height of more than 300 feet; but above this there is a flat at the height of 448 feet. This beach appears to become a wide terrace further to the North, and also on the opposite side of the bay. It probably corresponds with the highest terrace observed by Sir W. E. Logan. at Bay St. Paul, and estimated by him at the height of 360 feet.

As already stated, three of the principal terraces at Murray Bay correspond nearly with three of the principal shore levels at Montreal; and in various parts of Canada, two principal lines of old sea beaches occur at about 100 to 150 feet, and 300 to 350 feet above the sea, though there are others at different levels.

In the Post-pliocene period the valley of the Murray Bay river has been filled, almost or quite to the level of the highest terrace, with an enormously thick mass of mud and boulders, washed from the land and deposited in the sea bed during the long period of Post-pliocene submergence. Through this mass the deep valley of the river has been cut, and the clay, deprived of support and resting on inclined surfaces, has slipped downward, forming strangely shaped slopes, and outlying masses, that have in some instances been moulded by the receding waves, or by the subsequent action of the weather, into conical mounds, so regular that it is difficult to convince many of the visitors to the bay that they are not artificial. Sir W. E. Logan in his report on the district has in my view given the true explanation of these mounds, which

may be seen in all stages of formation on the neighbouring hill sides. Their effect to a geological eye is to give to this beautiful valley an unfinished aspect, as if the time elapsed since its elevation had not been sufficient to allow its slopes to attain to their fully rounded contour. This appearance is no doubt due to the enormous thickness of the deposit of Post-pliocene mud, to the uneven surfaces of the underlying rock, and possibly also in part to the earthquake shocks which have visited this region.

At the mouth of the Murray Bay River, the Boulder-clay, which rests directly on the striated rock surfaces, and which is a true till, filled with the Laurentian stones and boulders of the inland hills, though resting on Silurian limestone, is evidently marine, since it contains shells of *Leda truncata;* and many of the stones are coated with Bryozoa and *Spirorbes.* It is also observable that on the N.E. sides of the limestone ridges the boulders are more numerous and larger. Above the Boulder-clay may in some places be seen a stratified sandy clay, which further up the river attains to a great thickness. It contains *Saxicava rugosa*, *Tellina Grœnlandica*, and *Tellina calcarea*, as well as *Leda truncata.* The most recent deposit is a sand or gravel, often of considerable thickness, and in some of the beds of gravel the pebbles are more completely rounded than those of the modern beach.

I have already, in Section I, stated my reasons for believing that the upper part of the valley of the Murray Bay River may have been the bed of a glacier flowing down from the inland hills toward the St. Lawrence. N.W. and S.E. striæ attributable to this glacier were seen at an elevation of 800 feet, and the marine beds were traced up to almost the same height, above which, to a height of about 1200 feet, loose boulders were observed and glaciated rock surfaces, but no marine deposits. It is probable, therefore, that at a time when the sea extended up to an elevation of 800 feet, the higher part of the valley may have been filled with land ice. Whether the bergs from this, drifting down toward the St. Lawrence, produced the N.W. striation observed at a lower level, or whether at a previous period, when the land was higher, the ice extended farther down, may admit of doubt. Certainly no land ice has extended to a lower level than about 800 feet, since the deposition of the marine boulder and Leda clay.

Very large boulders occur in this vicinity. One observed on the beach on the east side of the Bay, is an oval mass of lime felspar, thirty feet in circumference, lying like most other large boulders in this region, with its longer axis to the N.E.

Les Eboulements.—At this place the Laurentian hills rise to a great height near the shore, and the Post-pliocene beds present the exceptional feature of resting on soft decomposed Silurian shale (Utica shale). This rock might indeed be mistaken for drift, but for its stratification, and it must have been decomposed to a great depth by subaerial action and subsequently submerged and covered by the Post-pliocene beds. Its preservation is the more remarkable that the clay overlying it contains very large Laurentian boulders, which must have been quietly deposited by floating ice. Only a few shells of *Tellina Grœnlandica* were observed in these clays.

The remarkable series of terraces seen at this place, and noticed in part first, rising to 900 feet in height, are all cut out of the Post-pliocene beds and decomposed shale, and even the highest presents large boulders. In examining such terraces it is always necessary to distinguish between the clays out of which the terraces have been cut and the more modern deposits resting on the terraces. Both may contain fossils, but those of the original clay are in this region mostly of deeper water species than those in the overlying superficial beds.

I attribute the preservation of the thick beds of Boulder-clay and the decomposed shale at Les Eboulements, to the fact that no transverse valley exists here, and that a point of high Laurentian land projects to the North-East, so as to shelter this place from forces acting in that direction. I have observed this appearance on the lee or South-west side of other projecting masses of hard rock, and as the decomposed shale must be a monument remaining from the Pliocene elevation of the land, it shews that no powerful eroding force had acted between that time and the period of the N. E. arctic ice-laden currents.

It is perhaps deserving of notice that the thick beds of soft material at Les Eboulements have been cut into many irregular forms by modern subærial causes of denudation, and also by landslips, which last have been in part connected with the earthquake shocks with which this part of the coast has been visited more than any other district of Canada.

Above Les Eboulements, Bay St. Paul presents features similar to those of Murray Bay, and then the Laurentian land of Cape Tourment comes boldly forward to the shore of the River. Above this the conditions are similar to those observed in the neighbourhood of Quebec.

5. *Lower St. Lawrence—South Side.*

The Report of the Geological Survey of Canada (1863), includes all that is yet known of the Post-pliocene formations at Gaspé, and thence upward to Trois Pistoles. According to this Report, the Boulder-clay and overlying sands and gravels are extensively spread over the Peninsula of Gaspé. On the Magdalen River they have been traced up to a height of 1600 feet above the sea, though marine shells are not recorded at this great height. Terraces occur at various elevations, and in one of the lower at Port Daniel, only fifteen feet above the sea, marine shells occur. On the coast westward of Cape Rosier, terraces occur at many places, and of different heights, and marine shells have been found ninety feet above the sea. I have not had opportunities to examine these deposits to the eastward of the place next to be mentioned.

Trois Pistoles.—At this place one of the most complete and instructive sections of the Post-pliocene in Canada, has been exposed by the deep ravine of the river, and by the cuttings for the Intercolonial Railway. The most important terrace at the mouth of the Trois Pistoles River, that in which the railway cutting has been made, is about one hundred and fifty feet above the level of the sea, and is composed of clay capped with sand and gravel. At no great distance inland, there rises a second terrace one hundred and sixty feet higher than the first, or about three hundred and ten feet above the sea. In some places the front of this terrace is cut into two or more. It consists of clay capped with sand and gravel, with some large stones and Laurentian boulders. Still farther inland is a third terrace, the height of which was estimated at four hundred to four hundred and fifty feet.

In the first mentioned of the above terraces, a very deep railway cutting has been made, exposing a thick bed of homogeneous clay of a purplish gray colour and extremely tenacious. It contains few fossils; and these, as far as I could ascertain, exclusively *Leda truncata*. It is, in short, a typical Leda clay, and its thickness in this lower terrace can scarcely be less than one hundred and twenty feet. As the inland terraces are probably also cut out of it, this may be less than half of its maximum depth. Under the Leda clay a typical Boulder-clay had been exposed at one place in digging a mill sluice. It seemed to be about twenty

feet thick, and rests on the smoothed edges of the shales of the Quebec group.

Though the Leda clay at the Trois Pistoles seems perfectly homogeneous, it shows indications of stratification, and holds a few large Laurentian boulders, which become more numerous in tracing it to the westward. A short distance westward of Trois Pistoles, it is seen to be overlaid by a boulder deposit, in some places consisting of large loose boulders, in others approaching to the character of a true Boulder-clay or associated with stratified sand and gravel. We thus have Boulder-clay below, next Leda clay, and above this a second Boulder drift associated with the Saxicava sand, and apparently resting on the terraces cut out of the older clays. This is the arrangement which prevails throughout this part of Canada. It is modified by the greater or less relative thickness of the Boulder-clay and Leda clay, by the irregular distribution of the overlying sands, and by the projection through it of ridges of the underlying rocks.

The section at Trois Pistoles may be represented as follows in descending order:

1. *Sand and Gravel*, capping the terraces cut in the previous deposits, and forming slight ridges or eskers in some of the lower levels. It contains on the lower terraces a few shells of *Leda* and *Tellina*. At the bottom of this deposit there are seen in places many large boulders of Laurentian and Lower Silurian rocks, resting on the Leda clay below.

2. *Leda Clay*, exposed in the railway cutting and seen also in the edge of the second terrace. Thickness one hundred and twenty feet or more. It holds a few large boulders and shells of *Leda truncata*—the latter uninjured and with the valves united.

3. *Boulder clay*, or hard gray till, with boulders and stones. Seen in a mill-sluice near the bridge, and estimated at twenty feet in thickness, at this place; though apparently increasing in thickness farther to the westward.

4. *Shales* of Lower Silurian age, seen in the bottom of the River near the bridge. They are smoothed over, but show no striæ, though they have numerous structure lines which might readily be mistaken for ice-striæ.

To the eastward of the mouth of Trois Pistoles River, the first terrace above-mentioned is brought out to the shore by a projecting point of rock. In proceeding westward toward Isle Verte, it recedes from the coast, leaving a flat of considerable breadth, which represents the lowest terrace seen on this part of the St. Lawrence, and is elevated only a few feet above the sea. This flat is in many places thickly strewn with large boulders, probably left when it was excavated out of the clay. In proceeding westward the first or railway terrace of Trois Pistoles, inland of the flat above mentioned, is seen to consist of Boulder-clay, either in consequence of this part of the deposit thickening in this direction, or of the Leda clay passing into Boulder-clay. It still, however, at Isle Verte, contains a few shells of *Leda truncata* in tough reddish clay holding boulders.

Rivière-du-Loup and Cacouna.—The country around Cacouna and Rivière-du-Loup rests on the shales, sandstones, and conglomerates of the Quebec and Potsdam groups of Sir W. E. Logan. As these rocks vary much in hardness, and are also highly inclined and much disturbed, the denudation to which they have been subjected has caused them to present a somewhat uneven surface. They form long ridges running nearly parallel to the coast, or north-east and south-west, with intervening longitudinal valleys excavated in the softer beds. One of these ridges forms the long reef off Cacouna, which is bare only at low tide; another, running close to the shore, supports the village of Cacouna; another forms the point which is terminated by the pier; a fourth rises into Mount Pilote; and a fifth stretches behind the town of Rivière-du-Loup.

The depressions between these ridges are occupied with Post-pliocene deposits, not so regular and uniform in their arrangement as the corresponding beds in the great plains higher up the St. Lawrence, but still presenting a more or less definite order of succession. The oldest member of the deposit is a tough Boulder-clay, its cement formed of gray or reddish mud derived from the waste of the shales of the Quebec group, and the stones and boulders with which it is filled partly derived from the harder members of that group, and partly from the Laurentian hills on the opposite or northern side of the river, here more than twenty miles distant. The thickness of this Boulder-clay is, no doubt, very variable, but does not appear to be so great as farther to the eastward.

Above the Boulder-clay is a tough clay with fewer stones, and above this a more sandy Boulder-clay, containing numerous boulders, overlaid by several feet of stratified sandy clay without boulders; while on the sides of the ridges, and at some places near the present shore, there are beds and terraces of sand and gravel, constituting old shingle beaches apparently much more recent than the other deposits.

All these deposits are more or less fossiliferous. The lower Boulder-clay contains large and fine specimens of *Leda truncata* and other deep-water and mud-dwelling shells, with the valves attached. The upper Boulder-clay is remarkably rich in shells of numerous species; and its stones are covered with Polyzoa and great Acorn-shells (*Balanus Hameri*), sometimes two inches in diameter and three inches high. The stratified gravel holds a few littoral and sub-littoral shells, which also occur in some places in the more recent gravel. On the surface of some of the terraces are considerable deposits of large shells of *Mya truncata*, but these are modern, and are the 'kitchen-middens' of the Indians, who in former times encamped here.

Numbers of Post-pliocene shells may be picked up along the shores of the two little bays between Cacouna and Rivière-du-Loup; but I found the most prolific locality to be on the banks of a little stream called the Petite Rivière-du-Loup, which runs between the ridge behind Cacouna and that of Mount Pilote, and empties into the bay between Rivière-du-Loup and the pier. In these localities I collected and noticed in my paper on this place* more than eighty species, about thirty-six of them not previously published as occurring in the Post-pliocene of Canada.

We have thus at Rivière-du-Loup indubitable evidence of a marine Boulder-clay, and this underlies the representative of the Leda clay, and rests immediately on striated rock surfaces—the striæ running north-east and south-west.

The Cacouna Boulder-clay is a somewhat deep-water deposit. Its most abundant shells are *Leda truncata*, *Nucula tenuis*, and *Tellina proxima*, and these are imbedded in the clay with the valves closed, and in as perfect condition as if the animals still inhabited them. At the time when they lived, the Cacouna ridges must have been reefs in a deep sea. Even Mount Pilote has huge Laurentian boulders high up on its sides, in evidence

* *Canadian Naturalist*, April, 1865.

of this. The shales of the Quebec group were being wasted by the waves and currents; and while there is evidence that much of the fine mud worn from them was drifted far to the south-west to form the clays of the Canadian plains, other portions were deposited between the ridges, along with boulders dropped from the ice which drifted from the Laurentian shore to the north. The process was slow and quiet; so much so that in its later stages many of the boulders became encrusted with the calcareous cells of marine animals before they became buried in the clay. No other explanation can, I believe, be given of this deposit; and it presents a clear and convincing illustration, applicable to wide areas in Eastern America, of the mode of deposit of the Boulder-clay.

A similar process, though probably on a much scaller scale, is now going on in the Gulf. Admiral Bayfield has well illustrated the fact that the ice now raises, and drops in new places, multitudes of boulders, and I have noticed the frequent occurrence of this at present on the coast of Nova Scotia. At Cacouna itself, there is, on some parts of the shore, a band of large Laurentian boulders between half tide and low-water mark, which are moved more or less by the ice every winter, so that the tracks cleared by the people for launching their boats and building their fishing-wears, are in a few years filled up. Wherever such boulders are dropped on banks of clay in process of accumulation, a species of Boulder-clay, similar to that now seen on the land, must result. At present such materials are deposited under the influence of tidal currents, running alternately in opposite directions; but in the older Boulder-clay period, the current was probably a steady one from the north-east, and comparatively little affected by the tides.

The Boulder-clay of Cacouna and Rivière-du-Loup, being at a lower level and nearer the coast than that found higher up the St. Lawrence valley, is probably newer. It may have been deposited after the beds of Boulder-clay at Montreal had emerged. That it is thus more recent, is farther shown by its shells, which are, on the whole, a more modern assemblage than those of the Leda clay of Montreal. In fossils, as well as in elevation, these beds more nearly resemble those on the coast of Maine. It would thus appear that the Boulder-clay is not a continuous sheet or stratum, but that its different portions were formed at different times, during the submergence and elevation of the country; and

must have been during the latter process that the greater part of the deposits now under consideration were formed.

The assemblage of shells at Rivière-du-Loup, is, in almost every particular, that of the modern Gulf of St. Lawrence, more especially on its northern coast. The principal difference is the prevalence of *Leda truncata* in the lower part of the deposit. This shell, still living in Arctic America, has not yet occurred in the Gulf of St. Lawrence, but is distributed throughout the lower part of the Post-pliocene deposits in the whole of Lower Canada and New England, and appears in great numbers at Rivière-du-Loup, not only in the ordinary form, but in the shortened and depauperated varieties which have been named by Reeve *L. siliqua* and *L. sulcifera.*

Of *Astarte Laurentiana*, supposed to be extinct, and which occurs so abundantly in the Post-pliocene at Montreal, few specimens were found, and its place is supplied by an allied but apparently distinct species, to be noticed in the sequel, which is still abundant at Gaspé and Labrador, and on the coast of Nova Scotia.

It must be observed that though the clays at Rivière-du-Loup are more recent than those of Montreal, they are still of considerable antiquity. They must have been deposited in water perhaps fifty fathoms deep, and the bottom must have been raised from that depth to its present level; and in the meantime the high cliffs now fronting the coast must have been cut out of the rocks of the Quebec group.

The order of succession of beds, as seen in the banks of the Little Rivière-du-Loup, may be stated as follows, in descending order:

1. Large Loose Boulders, mostly of Laurentian rocks, seen in the tops of ridges of rock and gravel. One angular mass of Quebec group conglomerate was observed ninety feet in circumference and ten to fifteen feet high. Near it was a rounded boulder of Anorthosite Felspar from the Laurentian, 13 feet long.
2. Stratified sand and gravel resting on the sides of the ridges of rock projecting through the drift. Thickness variable.
3. Stratified sandy clay and sand with *Tellina Grœnlandica* and *Buccinum.* 10 feet.

4. Gray clay and stones. *Rhynconella psittacea*, and *Terebratulina Spitzbergensis*, &c. 1 foot or more.

5. Gray clay with large stones, often covered with Bryozoa and Acorn-shells. *Tellina calcarea* very abundant, also *Leda truncata*. 3 feet.

6. Tough, hard, reddish clay, with stones and boulders, passing downward into Boulder-clay, and holding *Leda truncata*. 6 feet or more.

It was observable that the boulders were more abundant on the south side of the ridges than on the north; and between Rivière-du-Loup and Quebec there are numerous small ridges and projecting masses of rock rising above the clays, which generally show the action of ice on their N. E. sides; while the large boulders lying on the fields are seen to have their longer axes N. E. and S. W.

At the Petite Rivière-du-Loup the surface of the red clay (No. 6 above) was observed to have burrows of *Mya arenaria*, with the shells (of a deep-water form) still within them.

6. *River St. Lawrence above Quebec, and Ottawa Valley.*

Quebec and its Vicinity.—The deposits at Beauport, near Quebec, were described by Sir C. Lyell in the Geological Transactions for 1839; and a list of their fossils was given, and was compared with those of Montreal in my paper of 1859. As exposed at the Beauport Mills, the Post-pliocene beds consist of a thick bed of Boulder-clay, on which rests a thin layer of sand with *Rhynconella psittacea* and other deep-water shells. Over this is a thick bed of stratified sand and gravel filled with *Saxicava rugosa* and *Tellina*. In a brook near this place, and also in the rising ground behind Point Levi, the deep-water bed attains to greater thickness, but does not assume the aspect of a true Leda clay. Above Quebec, however, the clays assume more importance; and between that place and Montreal are spread over all the low country, often attaining a great thickness, and not unfrequently capped with the Saxicava sand. At Cap a la Roche the officers of the Geological Survey have found a bed of stratified sand under the Leda clay. The Beauport deposit is evidently somewhat exceptional in its want of Leda clay, and this I suppose may have been owing to the powerful currents of water

which have swept around Cape Diamond at the time of the elevation of the land out of the Post-pliocene sea. The layer of sand at the surface of the Boulder-clay is evidently here the representative of the Leda clay, and affords its characteristic fossils, while the stones projecting above the Boulder-clay are crusted with Bryozoa and Acorn-shells. At St. Nicholas, there is a sandy Boulder-clay, not unlike that of Rivière-du-Loup, which has afforded some very interesting fossils. It is stated in the Report of the Survey to be one hundred and eighty feet above the sea.

Montreal.—In the neighbourhood of Montreal very interesting exposures of the Post-pliocene beds occur, and with the terraces on the Mountain have been described in my papers of 1857 and 1859. I may here merely condense the leading facts, adding those more recently obtained.

An interesting section of the deposits is that obtained at Logan's Farm, which may be thus stated in descending order:

	ft.	in.
Soil and sand,	1	9
Tough reddish clay,	0	0½
Gray sand, a few specimens of *Saxicava rugosa*, *Mytilus edulis*, *Tellina Grœnlandica*, and *Mya arenaria*, the valves generally united,	0	8
Tough reddish clay, a few shells of *Astarte Laurentiana, and Leda truncata*,	1	1
Gray sand, containing detached valves of *Saxicava rugosa*, *Mya truncata, and Tellina Grœnlandica:* also *Trichotropis borealis*, and *Balanus crenatus;* the shells, in three thin layers.	0	8
Sand and clay, with a few shells, principally *Saxicava* in detached valves.	1	3
Band of sandy clay, full of *Natica clausa*, *Trichotropis borealis*, *Fusus tornatus*, *Buccinun glaciale*, *Astarte Laurentiana*, *Balanus crenatus*, &c. &c., sponges and *Foraminifera*. Nearly all the rare and deep-sea shells of this locality occur in this band,	0	3
Sand and clay, a few shells of *Astarte* and *Saxicava*, and remains of sea-weeds with *Lepralia* attached; also *Foraminifera*,	2	0
Stony clay (Boulder-clay). Depth unknown.		

In this section the greater part of the thickness corresponds to the Leda clay, which at this place is thinner and more fossiliferous than usual. Along the south-east side of the Mountain, and in the city of Montreal, the beds have been exposed in a great num-

ber of places, and are in the aggregate at least 100 feet thick, though the thickness is evidently very variable. The succession may be stated as follows:

1. *Saxicava Sand.*—Fine uniformly grained yellowish and gray silicious sand with occasional beds of gravel in some places, and a few large Laurentian boulders, *Saxicava*, *Mytilus*, &c., in the lower part. Thickness variable, in some places 10 feet or more.

2. *Leda Clay.*—Unctuous gray and reddish calcareous clay, which can be observed to be arranged in layers varying slightly in colour and texture. Some of these layers have sandy partings in which are usually Foraminifera and shells or fragments of shells. In the clay itself the only shells usually found are *Leda truncata* and a smooth deep-water form of *Tellina Grœnlandica;* but toward the surface of the clay in places where it has not been denuded before the deposition of the overlying sand, there are many species of marine shells. A few large boulders are scattered through the Leda clay.

3. *Boulder-clay.*—Stiff gray stony clay or till, with large boulders and many glaciated stones, often of the same Trenton rocks which occur on the flanks of the Mountain. It is of great thickness, though it has been much denuded in places, and has not been observed to contain fossils. It is especially thick at the south and south-west sides of the Montreal Mountain.

The Montreal Mountain, like other isolated trappean hills in the great plain of the Lower St. Lawrence, presents a steep craggy front to the north-east, and a long slope or tail to the south-west; and in front of its north-east side is a bare rocky plateau of great extent, and at a height of rather more than 100 feet above the river. This plateau must have been produced by marine denudation of the solid mass of the Mountain in the Post-pliocene period, and proves an astonishing amount of this kind of erosive action in hard limestones interleaved with trap dykes, and which have been ground and polished with ice at the same time that the plateau was cut into the hill. By ice also must the debris produced by this enormous erosion have been removed, and piled along the more sheltered sides of the hill in the Boulder-clay.

With regard to the crag-and-tail attitude of Montreal Mountain, I have to observe that in large masses of this kind reaching to a considerable height, and rising above the Post-pliocene sea, the north-east or exposed side has been cut into steep cliffs, but in smaller projections of the surface over which the ice could grind, the exposed side is smoothed or "moutonnée," and the sheltered side is angular. A little reflection must show that this must be the necessary action of a sea burdened with heavy floating ice.

The most strongly marked terraces on the Montreal Mountain, are at heights of 470, 440, 386, and 220 feet above the sea, but there are less important intermediate terraces. On the highest of these, on the west side of the Mountain, over Cote des Neiges village, there is a beach with marine shells, and on the summit of the Mountain, at a height of about 700 feet, there are rounded surfaces, probably polished by ice, though no striation remains, and large Laurentian boulders, which must have been carried probably a hundred miles from the Laurentian regions to the north-east, and over the deep intervening valley of the St. Lawrence.

I have already, in the first part of this memoir, noticed the striation on rock surfaces at Montreal, and may merely add that it is often very perfect, and must have been produced by a force acting up the St. Lawrence valley from the north-east, and planing all the spurs of the Mountain on that side, while leaving the Mountain itself as a bare and rugged unglaciated escarpment. In the streets of Montreal the true Boulder-clay is often exposed in excavations, and is seen to contain great numbers of glaciated stones, most of which are of the hardened Lower Silurian shales and limestones of the base of the Mountain; and though no marine shells have been found, the sub-aquatic origin of the mass is evidenced by its gray unoxidised character, and by the fact that many of the striated stones at once fall to pieces when exposed to the frost, so that they cannot possibly have been glaciated by a sub-aerial glacier.

At the Glen brick-work, near Montreal, the Leda clay and underlying deposits have been excavated to a considerable depth, and present certain remarkable modifications. The section observed at this place is as follows:

	ft.	in.
1. Hard gray laminated clay, *Foraminifera* and *Leda*, in thin layers	7	0
2. Red layer, in two bands	0	6
3. Sandy clay	1	0
4. Gray and reddish clay	9	0
5. Hard buff sand, very fine and laminated	15	0
6. Sand with layers of tough clay, holding glaciated stones, and very irregularly disposed	4	0
7. Fine sand	1	0
8. Gray sand, with rounded pebbles, and laminated obscurely and diagonally	4	0
9. Fine laminated yellow sand	3	0
10. Gravel	0	4
11. Very irregular mass of laminated sand, with mud, gravel, stones and large boulders	12	0
	56	10

The whole of these deposits except the Leda clay, are very irregularly bedded, and are apparently of a littoral character. They seem to shew the action of ice in shallow water before the deposition of the Leda clay. The only way of avoiding this conclusion would be to suppose that the underlying beds are really of the age of the Saxicava sand, and that the Leda clay has been placed above them by slipping fram a higher terrace; but I failed to see good evidence of this. A little farther west at the gravel pits dug in the terrace for railway ballast, a deep section is exposed showing at the top Saxicava sand, and below this a very thick bed of sandy clay with stones and boulders, constituting apparently a somewhat arenaceous and partially stratified equivalent of the Boulder-clay. A little above this place, at the Brick-works, the Saxicava sand is seen to rest on a highly fossiliferous Leda clay, which probably here intervenes between the two beds seen in contact nearer the edge of the terrace.

Ottawa River.—The Leda clay and Saxicava sand are well exposed on the banks of the Ottawa; and Green's Creek, a little below Ottawa City, has become celebrated for the occurrence of hard calcareous nodules in the clay, containing not only the ordinary shells of this deposit, but also well-preserved skeletons of the Capelin (*Mallotus*) of the Lump-sucker (*Cyclopterus*) and of a species of stickleback (*Gasterosteus*). Some of these nodules also contain leaves of land plants and fragments of wood, and a fresh-water shell of the genus Lymnea has also been found.

At Packenham Mills west of the Ottawa, the late Sheriff Dickson found several species of land and fresh-water shells associated with Tellina Grœnlandica and apparently in the Saxicava sand. These facts evidence the vicinity of the Laurentian shore, and indicate a climate only a little more rigorous than that of Central Canada at present. They were noticed in some detail in my paper of 1866 in *The Canadian Naturalist*..

The marine deposits on the St. Lawrence are limited, as already stated, to the country east of Kingston; and the clays of the basin of the great lakes to the south-westward have, as yet, afforded no marine fossils. I have, however, just learned from Prof. Bell, of the Geological Survey, a discovery made by him in the past summer and which is of very great interest, namely that two hundred miles north of Lake Superior the marine deposits reappear. The details of this important discovery will be given in a forthcoming Report of the Geological Survey, and its theoretical significance will be referred to in the concluding part of this memoir.

In the above local details, I have given merely the facts of greatest importance, and may refer for many subordinate points to the papers catalogued in the introduction to this memoir, and to the reports of the Geological Survey of Canada.

Fig. 1.

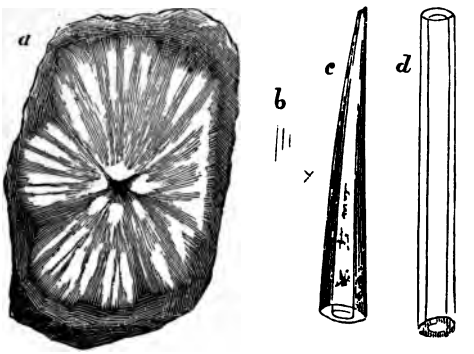


Fig. 2.

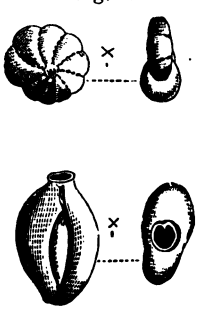


Fig. 3.

Fig. 4.

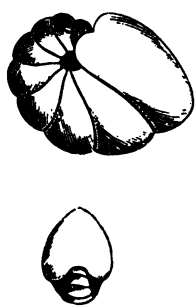
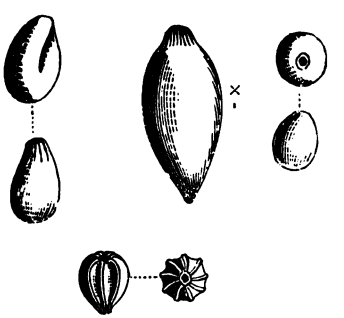


Fig. 5.



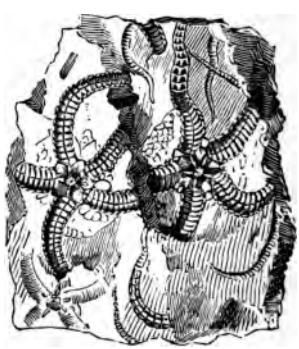


Fig. 1. *Tethea Logani*, Montreal, (*a*) Mass of Spicules in clay; (*b c d*) Spicules, (natural size and magnified.)

Fig. 2. Group of Common Foraminifera from Montreal. (magnified.) *Polystomella crispa; Quinqueloculina seminulum; Polymorphina lactea*, two varieties; *Entosolenia globosa* and *E. costata.*

Fig. 3. *Truncatulina lobulata.* (magnified.)

Fig. 4. *Nonionina scapha.*—Var. *Labradorica.* (magnified.)

Fig. 5. *Ophioglypha Sarsii*, Duck Cove, St. John, N. B.

PART III.—REVISION OF POST-PLIOCENE FOSSILS OF CANADA.

The list of Post-pliocene fossils published previously to 1856, amounted to only about 26 species. In my papers published between that year and 1863, the number was raised to nearly 80. My lists were tabulated, along with some additional species furnished in MS, in the Report of the Geological Survey for 1863, the list there given amounting to 83 species, exclusive of Foraminifera. In my paper on the Post-pliocene of Rivière-du-Loup and Tadoussac, published in 1865, I added 38 species, and shall be able still farther to increase the number in the present revision, which will afford a very complete view of the subject up to the present time; and though additional species will no doubt be found, yet all the principal deposits have been so carefully explored that only very rare species can have escaped observation. For some of the additional species included in the present list, I am indebted to Mr. G. T. Kennedy of Montreal, Dr. Anderson of Quebec, and other friends, to whom reference will be made in connection with the several species in the catalogue.

SUB-KINGDOM RADIATA.

Class I.—Protozoa.

(1) *Foraminifera.*

Nodosaria (*Glandulina*) *lævigata.*

——————————(Var. *Dentalina communis*)

Fossil—Leda clay, Montreal.

Recent—Gulf St. Lawrence, 30 to 300 fathoms, G.M.D.*

This species is very rare in the Post-pliocene, but sometimes of large size and of different varietal forms.

---

* The initials G. M. D., refer to the List of Foraminifera by Mr. G. M. Dawson in *The Canadian Naturalist*, 1870.

Lagena Sulcata —— (Var. *distoma.*)
———————— (Var. *semisulcata.*)

Fossil—Leda clay, Montreal; Quebec; Murray Bay; Rivière-du-Loup; Portland (Maine.)

Recent—Gulf St. Lawrence, 18 to 313 fathoms, G.M.D.

Rather rare in the Post-pliocene as well as in the recent.

Entosolenia globosa.
————————*costata.*
————————*marginata.*
————————*squamosa.*

Fossil—Montreal, Leda clay; Labrador; Rivière-du-Loup; Murray Bay; Quebec; Portland (Maine).

Recent—Gulf and River St. Lawrence, 20 to 313 fathoms. G. M. D.

Generally diffused in the Post-pliocene, and presenting the same range of forms as in the recent; but not common. I regard the supposed species of *Entosolenia* above named as merely varietal forms.

Bulimina Presli.
———————— (Var. squamosa)

Fossil—Montreal, Leda clay; Labrador; Rivière-du-Loup; Murray Bay; Quebec; Portland (Maine).

Recent—Gulf and River St. Lawrence, 10 to 313 fathoms, G. M. D.

Generally diffused in the Post-pliocene. In the recent it seems to be a deep-water form. What Parker and Jones call the essentially arctic form *B. elegantissima* is not uncommon, though other forms also occur.

Polymorphina lactea.

Fossil—Montreal, Leda clay; Labrador; Rivière-du-Loup; Murray Bay.

Recent—Gulf and River St. Lawrence, 30 to 313 fathoms. G. M. D.

Not uncommon in the Post pliocene, particularly in the deeper parts of the Leda clay. Less common recent. I observed in the Rivière-du-Loup gatherings a small individual of this species with the internal pipe at the aperture characteristic of Entosolenia, which is also sometimes observed in recent specimens.

Truncatulina lobulata.

Fossil—Leda clay, Labrador; Rivière-du-Loup.

Recent—Gulf St. Lawrence, very common 30 to 50 fathoms.

This species is much less common in the Post-pliocene than in the recent.

Orbulina universa.

Fossil—Leda clay, Montreal; Rivière-du-Loup; Labrador.

This may be regarded as a rare and somewhat doubtful Post-pliocene fossil. It has not yet been recognized in the Gulf of St. Lawrence.

Globigerina bulloides.

Fossil—Rivière-du-Loup.

Recent—Gulf St. Lawrence, more espccially in the deeper water, where it is common. It is very rare in the Post-pliocene.

Pulvinulina repanda.

Fossil—Montreal, Leda clay; Rivière-du-Loup; Murray Bay; Labrador; Quebec; Portland (Maine).

Recent—Gulf St. Lawrence, 30 to 313 fathoms, G. M. D.

Somewhat rare both in the Post-pliocene and recent, and of the small size usual in the arctic seas.

Polystomella crispa.—(Var. *Striatopunctata*).

——————— (Var. *Arctica.*)

Fossil—Montreal, Leda clay; Labrador; Rivière-du-Loup; Murray Bay; Quebec; Portland (Maine); St. John, N. B.

Recent—Gulf and River St. Lawrence, 30 to 40 fathoms. G. M. D.

Very common, especially in depths of 10 to 40 fathoms. This is by far the most abundant species in the Post-pliocene deposits, as it is also in all the shallow parts of the Gulf of St. Lawrence at present, and also in the Arctic Seas, according to Parker and Jones. It is the only species yet found in the Boulder-clay of Montreal, and this very rarely.

Nonionina scapha.

———————(Var. *Labradorica.*)

Fossil—Leda clay, Montreal; Rivière-du-Loup; Labrador; Murray Bay; Quebec; St. John, N. B.

Recent—Gulf and River St. Lawrence, 10 to 313 fathoms. Var. *Labradorica* is the deeper water form and is rare in the Leda clay.

Textularia pygmæa.

Fossil—Leda clay, Labrador; Rivière-du-Loup; Quebec; also at Portland (Maine).

Recent—Gulf St. Lawrence, 10 to 30 fathoms.

The Textulariæ are rare and of small size, both in the Post-pliocene and recent.

Cornuspira foliacea.

Fossil—Leda clay, Montreal.

Recent—Gulf St. Lawrence, 16 to 250 fathoms, G. M. D.

This species is rare both fossil and recent.

Quinqueloculina seminulum.

Fossil—Leda clay, Montreal; Labrador; Quebec; Portland (Maine).

Recent—Gulf St. Lawrence, 10 to 313 fathoms, most abundant in shallow water. G. M. D.

This species is by no means common and not usually large in the Post-pliocene. It is more abundant in the clays of Maine than in those of Canada.

Biloculina ringens.

Fossil—Leda clay, Montreal; Labrador; Rivière-du-Loup; Murray Bay; Quebec.

Recent—Gulf St. Lawrence, 30 to 313 fathoms. G. M. D.

Rather rare in the Post-pliocene as well as in the recent.

Triloculina tricarinata.

Fossil—Leda clay, Rivière-du-Loup; Murray Bay; Quebec.

Recent—Gaspé, 30 to 50 fathoms. G. M. D.

Rare both in Post-pliocene and recent, but perhaps more generally diffused in the former.

Lituola and *Saccammina.*

A very few minute sandy forms referable to these genera are found among the finer part of the washings from Riviére-du-Loup.

Euglypha?

A single minute test, apparently identical in form with that of *Euglypha alveolata*, was found in washing the Rivière-du-Loup clays.

In general terms it may be stated that all the species of Foraminifera found in the Post-pliocene still inhabit the Gulf and River St. Lawrence. Several species found in the Gulf of St. Lawrence have not yet been recognized in the Post-pliocene, and these are mostly inhabitants of depths exceeding 90 fathoms, or among the more southern forms found in the Gulf.

On the whole, the assemblage, as in the northern part of the Gulf of St. Lawrence at present, is essentially arctic, and not indicative of very great depths.

The sandy forms which are not uncommon in the Gulf are very rare in the Post-pliocene; but this may be accounted for by the greater difficulty of washing them out of the clay, or possibly their cementing material may have decomposed, allowing them to fall to pieces. As the epidermal matter of shells is often preserved, the last supposition seems less likely. The Leda clays are, however usually very fine and calcareous, so that there was probably more material for calcareous than for arenaceous forms.

The Foraminifera are very generally diffused in the Post-pliocene clays, though much more abundant in some layers than in others. They may easily be detected by a pocket lens, and are usually in as fine preservation as recent specimens, especially in the deeper and more tenacious layers of the Leda clay. They are however, usually most abundant in the somewhat arenaceous layers near the top of the Leda clay, and immediately below the Saxicava sand, and especially where this layer contains abundance of shells of Mollusca. I have nowhere found them more abundant or in greater variety than at the Glen Brick-work, Montreal, on the McGill College Grounds, and at Logan's Farm. At the Glen Brick-work a few worn specimens of Polystomella are contained in the beds underlying the Leda clay and equivalent to the Boulder-clay, which, however, has in general, in the vicinity of Montreal as yet afforded no marine fossils.

In searching for Foraminifera in the clays of Rivière-du-Loup, I have observed in the finer washings several species of Diatomaceæ; among these a species of Coscinodiscus very frequent in the deeper parts of the Gulf of St. Lawrence. But on the whole Diatoms appear to be rare in these deposits. In the Rivière-du-Loup clays I have also observed the pollen grains of firs and spruces.

The nomenclature used above is that of Parker and Jones, in their paper on the North Atlantic Soundings, in the Transactions

of the Royal Society. For figures of the species, I may refer to that memoir, and to my previous papers published in the *Naturalist.*

(2) *Porifera.*

Tethea Logani, Dawson.

Leda clay, Montreal. This species has not yet been recognised in a living state, though allied to *Tethea hispida*, Bowerbank, of the coast of Maine. Its spicules in considerable masses, looking like white fibres, are not uncommon in the Post-pliocene at Montreal.

Tethea?

Another silicious sponge is indicated by little groups of small spicules found at the Tanneries, near Montreal, by Mr. G. T. Kennedy, and at Riviere-du-Loup by the author. Its spicules are long and acerate, and much more slender than those of *Tethea Logani.* They resemble those of *T. hispida*, recent on the coast of Maine, and also those of a species of *Polymastia*, dredged by Mr. Whiteaves in the Gulf of St. Lawrence.

CLASS II.—ANTHOZOA.

CLASS III.—HYDROZOA.

No distinct organisms referable to the above groups have yet been found in the Post-pliocene deposits of Canada. As our recent fauna includes no stony coral, and the recent species of the Gulf of St. Lawrence have no parts likely to be preserved other than minute spicules, this is not to be wondered at. In washing the clays for Foraminifera, however, numerous fragments are obtained, which resemble portions of the horny skeletons of hydroids, though not in a state admitting of determination.

CLASS IV.—ECHINODERMATA.

(1) *Ophiuridea.*

Ophioglypha Sarsii, Lutken.

Fossil—Leda clay, near St. John, N. Brunswick; Mr. Matthew.

Recent—River St. Lawrence, at Murray Bay; also found of large size in deep water in the Gulf of St. Lawrence, by Mr. Whiteaves.

(Post-pliocene—Canada.)

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 6.

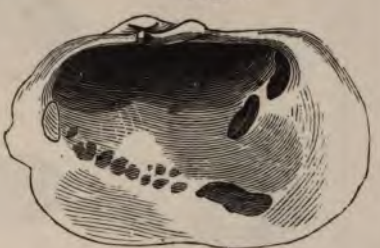


Fig. 5.

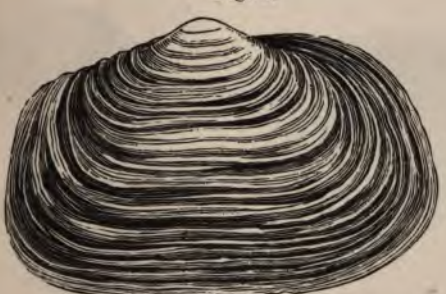


Fig. 7.

Fig. 8.

Fig. 1. *Lepralia quadricornuta*, Montreal (magnified).
Fig. 2. *Rhynchonella psittacea*, Riviere-du-Loup.
Fig. 3. *Terebratella Spitzbergensis*, Riviere-du-Loup.
Fig. 4. *Mya truncata*—Var. *Uddevallensis*—Montreal.
Fig. 5. *Mya truncata*—Var. *communis*—Portland.
Fig. 6. *Panopea Norvgica*, Riviere-du-Loup.
Fig. 7. *Saxicava rugosa*—Var. *Arctica*—Montreal.
Fig. 8. *Astarte Laurentiana*, Montreal.

Fig. 1.

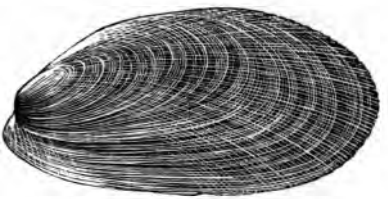


Fig. 2.

Fig. 3.

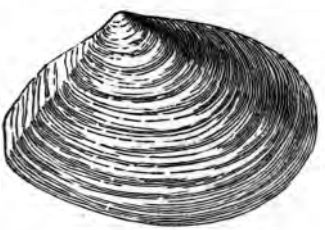


Fig. 5.

Fig. 4.

Fig. 6.

Fig. 9.

Fig. 10.

Fig. 7.

Fig. 11.

Fig. 8.

Fig. 1. *Modiolaria nigra*, Portland.
Fig. 2. *Mytilus edulis*—(Var. *elegans*)—Montreal.
Fig. 3. *Macoma calcarea*, Riviere-du-Loup.
Fig. 4. *Macoma Grœnlandica*, Riviere-du-Loup.
Fig. 5. *Macoma inflata*, Riviere-du-Loup.
Fig. 6. *Leda pernula*—(Var. *tenuisculata*)—Riviere-du-Loup.
Fig. 7. *Leda pernula*—(Var. *buccata*)—Riviere-du-Loup.
Fig. 8. *Leda minuta*, Riviere-du-Loup.
Fig. 9. *Leda* (*Portlandia*) *glacialis*, Montreal.
Fig. 10. *Nucula expansa*, Riviere-du-Loup.
Fig. 11. *Leda* (*Yoldia*) *limatula*, Riviere-du-Loup.

Ophiocoma.

Fragments of a small species of ophiuroid starfish not determinable, have been found in the Leda clay at Montreal, and in nodules at Green's creek.

(2) *Echinoidea.*

Euryechinus drobachiensis, Müller.

Fossil—Leda clay, Beauport; Rivière-du-Loup; Montreal.

This species is rare in the Post-pliocene, but very common in all parts of the Gulf of St. Lawrence at present.

(3) *Holothuridea.*

Psolus phantopus? Oken.

Scales of an animal of this kind have been found in the Leda clay at Montreal. They may belong to *P. phantopus*, or to the species *P.* (*Lophothuria*) *Fabricii*, also found on our coasts.

SUB-KINGDOM MOLLUSCA.

Introductory.—In preparing this, the largest and most important part of my catalogue, I have to acknowledge my obligations to Dr. P. P. Carpenter, for his kind aid in comparing all the more critical species of shells, and in giving me his valuable judgment as to their relations and synonymy, which I have in nearly every case accepted as final. I am also indebted to Dr. Carpenter for all the notices of West-coast shells.

To Mr. J. F. Whiteaves, F.G.S., I am indebted for reviewing the Polyzoa and comparing them with Smitt's Norwegian catalogues, and also for many valuable facts as to shells obtained in his recent dredgings in the Gulf of St. Lawrence.

To Mr. J. Gwyn Jeffreys, F.R.S., and Mr. R. McAndrew, F.R.S., of London, my grateful acknowledgments are due for aid and information, and also for the opportunity of comparing my specimens with those in their collections.

My comparisons with recent species have been made to a great extent with specimens dredged by myself, in the Gulf of St. Lawrence, and especially at Murray Bay, where the marine fauna seems to be more nearly related to that of the Post-pliocene

than in any part of the Gulf of St. Lawrence with which I am acquainted. I have also to acknowledge the use of specimens from Greenland, from Prof. Morch; from Norway from Mr. McAndrew; from Nova Scotia from Mr. Willis; as well as the use of the large and valuable collections of Dr. Carpenter and Mr. Whiteaves.

All the references in the following pages, except where authors are quoted, and many of these last, have been verified by myself by actual comparison of specimens.

The principal works to which I have referred in the publication of the catalogue are the following:

Beechey's Voyage, Natural History Appendix.
Belcher's Last of the Arctic Voyages, do.
Bell, Report on Invertebrata of Gulf of St. Lawrence.
Busk, Polyzoa of the Crag.
Crosskey on Post-pliocene of Scotland.
Fabricius, Fauna Grœnlandica.
Forbes and Hanley, British Mollusca.
Gould, Invertebrata of Massachusetts, edited by Binney.
Jeffreys' British Conchology.
Lyell on Shells collected by Capt. Bayfield; and Travels in North America.
Matthew on Post-pliocene of New Brunswick.
Middendorff, Shells of Siberia.
Packard on the Glacial Phenomena of Labrador and Maine.
Prestwich on the English Crag.
Sars on the Quaternary of Norway.
Stimpson, Shells of Hayes' Expedition, &c.
Whiteaves, Lists of Shells from Gulf of St. Lawrence, Canadian Naturalist.
Wood, Crag Mollusca.
Willis, Lists of Shells of Nova Scotia.

Class I.—Heterobranchiata.

Sub-Class I.—*Polyzoa*.

Hippothoa catenularia, Jameson.
Fossil—Beauport; Labrador; Rivière-du-Loup.
Recent—Gaspé*; Labrador (Packard).

* The references to Gaspé are from my list contributed to the Rept. Geol. Survey, 1858—Bell and Richardson, collectors; and from subsequent dredgings by myself and Mr. Whiteaves.

Hippothoa expansa, Dawson.
Fossil—Beauport; Rivière-du-Loup.
Recent—Gaspé; Labrador, Maine (Packard).

Tubulipora flabellaris, Johnston.
Fossil—Beauport; Rivière-du-Loup.
Recent—Gaspé, Labrador (Packard) (= *T. palmata*, Wood).

Lepralia hyalina, Johnston.
Fossil—Beauport; Rivière-du-Loup.
Recent—Gaspé.

Lepralia pertusa, Thomson.
Fossil—Beauport; Labrador; Rivière-du-Loup.
Recent—Gaspé, Labrador (Packard).

Lepralia quadricornuta, Dawson.
Fossil—Leda clay, Montreal.
Not yet found recent.

Mr. T. Curry, of Montreal, has recently found specimens in a very perfect state. They show that the cells are sculptured in a papillo-striate manner, and that the ovi-capsules are globular and granulate. Some cells have a projection for a vibraculum or avicularium at one side of the aperture. A few have two of these. Old colonies have a pitted calcareous deposit between the cells. The large size and narrow aperture with deep sulcas in front and four spines behind are as in the specimens formerly described.

Lepralia spinifera? Busk.
Fossil—Rivière-du-Loup.

L. violacea? Johnston.
Fossil—Rivière-du-Loup.

It wants the depression in front of the cell said to be characteristic of the species. (J. F. Whiteaves.)

L. variolosa, Johnston.
Fossil—Rivière-du-Loup.
Recent—Gaspé.

Dr. Smitt unites this with *L. trispinosa* of Johnston, and considers both as varieties of *L. Jacotini*, Audouin. *L. Jacotini*, Gray, is a very different species. (J. F. W.)

Lepralia Belli, Dawson.
Fossil—Rivière-du-Loup.
Recent—Gaspé; Labrador (Packard).

L. producta, Packard.
Fossil—Rivière-du-Loup.
Recent—Labrador (Packard); Gaspé; Murray Bay.

L. globifera, Packard.
Fossil—Riviére-du-Loup.
Recent—Labrador (Packard).

L. punctata ? Hassall.
Fossil—Rivière-du-Loup.
Recent—Gaspé.
The oral spines of this species cannot be made out in the fossil specimens I have seen. Smitt refers Hassall's species to D'Orbigny's sub-genus *Escharipora*. (J. F. W.)

L. Peachii, Johnston.
Fossil—Rivière-du-Loup.
Recent—Gaspé.
Rare in the Gulf of St. Lawrence. Smitt groups this species, together with *L. variolosa* (of Busk but *not* of Johnston) and *L. ventricosa*, as forms of *Discopora coccinea*. (J. F. W.)

Lepralia trispinosa, Johnston.
Fossil—Rivière-du-Loup.
Recent—Gaspé; Labrador (Packard).

Lepralia ventricosa, Hassall.
Fossil—Rivière-du-Loup.
Recent—Gulf St. Lawrence.

Diastopora obelia, Johnston.
Fossil—Rivière-du-Loup.
Recent—Gaspé.

Eschara elegantula, D'Orbigny.
Fossil—Rivière-du-Loup; Montreal (Curry).
Recent—Labrador (Packard); Gaspé.
Very fine and frequent in 10–30 fathoms opposite Cape Rosier Village. More abundant in the open river than in Gaspé and other bays. (J. F. W.)

Celleporaria surcularis, Packard.
Fossil—Rivière-du-Loup.
Recent—Labrador (Packard); Gaspé.
Smitt identifies this species with the *C. incrassata* of Lamarck. Abundant in 10–50 fathoms everywhere in the Gulf, and often drifted down to lower levels. (J. F. W.)

Myriozoum sub-gracile, D'Orbigny.

Fossil—Rivière-du-Loup.

Recent—Labrador (Packard); Gaspé.

Idmonea atlantica, Forbes.

Fossil—Rivière-du-Loup.

Recent—I believe this to be identical with a species found in the Gulf of St. Lawrence, and referred by Dr. Packard and Mr. Whiteaves to the above.

Crisia eburnea, Ellis.

Fossil—Montreal. A specimen collected by Mr. Curry is referred to this species by Mr. Whiteaves.

Recent—Labrador (Packard). In 96 fathoms, Trinity Bay, N. Shore St. Lawrence R. J. F. W.

Alecto, sp.

Fossil—Rivière-du-Loup.

Membranipora Lacroixii, Busk.

Fossil—Rivière-du-Loup.

Recent—Gaspé; Labrador (Packard).

Entirely agrees with recent examples from Gulf of St. Lawrence. One of the six forms referred by Smitt to *M. lineata* Linn. (J. F. W.)

Membranipora lineata, Linn.

Fossil—Rivière-du-Loup.

Recent—Gaspé.

Discoporella hispida, Johnston.

Fossil—Rivière-du-Loup. Patches on shells, somewhat worn, but referable to this common North Atlantic species.

Sub-Class II.—*Brachiopoda.*

Rhynchonella psittacea, Gm.

Fossil—Montreal; Beauport; Rivière-du-Loup. Abundant.

Recent—Murray Bay and Gaspé. Abundant. Labrador (Packard); Gulf St. Lawrence. Generally on stony bottoms 10 fathoms and over. Arctic seas generally; also Crag of England and glacial beds.

In a bed of stony clay at Riviére-du-Loup, this shell is very abundant, with less abundant specimens of the next species. It occurs living in precisely the same relations and in great abundance at Murray Bay, in about 20 fathoms.

Terebratella Spitzbergensis, Davidson.

Fossil—Rivière-du-Loup.

Recent—Murray Bay; also deeper parts of Gulf of St. Lawrence (Whiteaves); Nova Scotia (Willis).

This species has been found in the Post-pliocene of Canada, hitherto only at Rivière-du-Loup, and is rare. It was called *T. Labradorensis*, Sowerby, in former lists, which seems to be a synonym. It appears to be a rare shell in every part of the Gulf where it has hitherto occurred, except at Murray Bay, where it is not uncommon, and is found attached to stones in 20 to 25 fathoms, associated with *Rhynchonella psittacea.*

Class II.—Lamellibranchiata.

Pholas (Zirphea) crispata, Linn.

Fossil—Maine (Packard).

I have not found this species fossil in Canada, but it exists as a living shell on the New England coast generally, in Northumberland Strait; Gulf of St. Lawrence, and according to Bell as far to the north-west as Rimouski. Puget Sound (U. S. Expl. Exped.)

It has perhaps extended its northern limit to Canada since the glacial period. On the European coast it is a northern shell, reaching south to the Mediterranean.

Saxicava rugosa, Linn (and var. *Arctica*).

Fossil—Saxicava sand and top of Leda clay, Montreal; St. Nicholas; Ottawa; Quebec; Murray Bay; Rivière-du-Loup; Trois Pistoles; Tadousac; Labrador; Lawlor's Lake, New Brunswick; Maine, &c.

Recent—Gulf St. Lawrence; coast of Nova Scotia; and New England and northern seas generally; also west coast of America as far as Mazatlan. (P. P. Carpenter).

Very abundant in the more shallow portions of the Post-pliocene throughout Canada, and presenting all the numerous varietal forms of the species in great perfection. It is relatively much more abundant in the drift deposits than in the Gulf of St. Lawrence at present. Pieces of limestone which have been bored probably by this shell, are not rare in the drift at Montreal.

This is a widely distributed Arctic species, and is found in the Post-pliocene deposits of Europe, and as far back as the Miocene.

Panopœa Norvegica, Spengler.

Fossil—Leda clay; Rivière-du-Loup. Very rare.

Recent—Dredged in Gaspé Bay, 30 and 40 fathoms, by Mr. Whiteaves; Halifax (Willis); Grand Manan (Stimpson); Arctic and northern seas generally.

It is very rare in the Post-pliocene, a few valves only having been found at Rivière-du-Loup. The specimens are small, and much inferior to those found in the Scottish Clyde beds, of which I have a specimen from Rev. H. Crosskey.

Mya truncata, Linn. (and var. *Uddevallensis*).

Fossil—Saxicava sand and Leda clay; Montreal; Quebec; Rivière-du-Loup; Portland; New Brunswick (Matthew); Labrador (Packard); Greenland (Möller); also in the Post-pliocene of Europe.

Recent—Gulf St. Lawrence, but rare in comparison with its abundance in the drift. Generally distributed in the Arctic seas and North Atlantic, American coast as far south as Cape Cod; Puget Sound (=*preciosa*, Gould, P. P. C.)

The variety found in the Post-pliocene of Canada is the short or *Uddevallensis* variety, which is that occurring in the Arctic seas at present, while in the Gulf St. Lawrence the ordinary long variety is found almost exclusively. At Portland, Maine, however, the long variety lived in the Post-pliocene, and occasional specimens are found at Rivière-du-Loup. The form *Uddevallensis* occurs living in Labrador (Packard), and I have found it at Tadousac.

It is interesting to observe that while the present species is more abundant than the next in the Post-pliocene, it is much more rare in the Gulf at present. It also occurs in deeper water.

Mya arenaria, Linn.

Fossil—Leda clay and lower part of Saxicava sand; Montreal; Upton; Quebec; Murray Bay; Labrador; Duck cove and Lawlor's lake, New Brunswick; Portland, Maine; Greenland (Möller); also in the Post-pliocene of Europe.

Recent—Very abundant throughout the Gulf St. Lawrence and coast of Nova Scotia and New England, also Arctic seas generally. Mr. Jeffreys considers it identical with *M. Japonica*, Jay. Not found yet in W. America. (P. P. C.)

In the Gulf this species grows to a large size; I have a specimen five inches long from Gaspé; but in the Post-pliocene it is

small and often of a short and rounded variety. This is especially the case inland, as at Montreal. At Rivière-du-Loup a small thin variety with a strong epidermis and attenuated posteriorly, is found *in situ* in its burrows in the Leda clay. It may be a deep-water variety. Some large specimens in collections from this place, I have reason to believe are from Kitchen-middens and not fossils.

Kennerlia glacialis, Leach.

Fossil—Leda clay; St. John, New Brunswick; Saco, Maine.

Recent—Gaspé (Whiteaves); Murray Bay; Labrador (Packard).

This species, which was at first confounded with *Pandora trilineata* by Dr. Packard, is evidently quite distinct, and on the evidence of the hinge would belong to a different genus. Much nearer to *Pandora pinna*, Mont.; = *P. obtusa* Forbes and Hanley. J. F. W.

Lyonsia (*Pandorina*) *arenosa*, Möller.

Fossil—Leda clay; Montreal (rare and small); Rivière-du-Loup, common; Duck Cove, N. B.; Saco, Maine; also in Greenland (Möller).

Recent—Murray Bay and Gaspé; Halifax (Willis); Greenland (Möller); Labrador (Packard).

Some specimens from Portland are much larger than those from Rivière-du-Loup and Montreal, and Mr. Whiteaves finds individuals an inch long, living at Gaspé.

Thracia Conradi, Couthuoy.

Fossil—Saco (Packard).

Not yet found fossil in Canada, but recent, though rare, in Nova Scotia (Willis); and at Gaspé. Also, though apparently rare, at Labrador (Packard).

Has probably extended its northern limit to Canada, since the glacial period.

Macoma Grœnlandica, Beck.

Fossil—Saxicava sand and Leda clay; Montreal; Ottawa; Perth, Ont.; Pakenham Mills, Cornwall; Clarenceville; Upton; Quebec; Murray Bay; Rivière-du-Loup; Labrador; Lawlor's lake, N.B.; Campbellton, P. E. I.; Westbeach, Maine; Greenland (Möller).

Recent—Everywhere on the coasts of the Gulf and River St. Lawrence, as a common littoral shell.

A thin and delicate variety with smooth epidermis is found in the Leda clay; coarser and more wrinkled varieties in the Saxicava sand. Larger specimens are found at Quebec and Rivière-du-Loup than more inland.

In the modern Gulf, the small and depauperated varieties are littoral and near the brackish water, the finer varieties passing into *Macoma fusca* of Say, which is a southern variety, are found on the coast of Nova Scotia and in the Bay of Fundy. This shell is represented in the European seas and Post-pliocene deposits by the closely allied species *M. solidula* or *Balthica*, which seems to pass through a corresponding series of varieties, but to be distinct. On the western American coast it is similarly represented by *M. inconspicua*. Mr. Tryon and Mr. Whiteaves believe the three forms to be conspecific. (P. P. C.)

It is said to be the *Tellina Fabricii* of Hanley, and I have specimens from Greenland from Morch labelled *T. tenera*. The *T. tenera* of Leach, however, is *proxima*, Brown, teste Hanley. It is apparently the *Venus fragilis* of Fabricius.

It is one of the most common and abundant shells of the Post-pliocene, as it is of the American coast from Greenland to New England.

Macoma calcarea, Chemnitz.

Fossil—Leda and Boulder clays; Montreal; Quebec; Murray Bay; Rivière-du-Loup; Duck Cove, St. John, N.B.; Maine; Labrador; Greenland (Möller); also European Post-pliocene.

Recent—Arctic seas generally, and on the American coast south to Massachusetts.

This shell is is extremely abundant in the Leda and Boulder clays, and often occurs in the clay with the valves attached. It is also of large size and in fine condition, especially at Rivière-du-Loup. It is *Tellina proxima*, Brown, *T. sabulosa*, Spengler, and *T. sordida* of Couthuoy. According to Hanley, the *T. lata* of Gmelin was founded on a figure of this shell.

Macoma inflata, Stimpson.

Fossil—Montreal; Rivière-du-Loup. Rare.

Recent—Murray Bay, and dredged in deeper parts of the Gulf of St. Lawrence by Mr. Whiteaves.

I am not aware where this little shell has been described, nor what is its range. It seems identical with a specimen in Jeffrey's collection labelled *Tellina fragilis* Leach, from Spitzbergen.

The Post-pliocene specimens are larger and better developed than the recent, except some dredged by Mr. Whiteaves on the north shore, and I would infer from this that the shell is Arctic. (See Figure.)

Cyrtodaria siliqua, Daudin.

Fossil—Rivière-du-Loup; Labrador (Packard); Greenland (Möller). I have seen in the Post-pliocene of Canada, only an imperfect and decorticated specimen of the young shell, from Rivière-du-Loup.

Recent—Gulf of St. Lawrence, and coasts of Nova Scotia and New England.

Mactra (*Spisula*) *ovalis*, Gould.

M. polynema, Stimpson.

Fossil—Boulder clay; Cape Elizabeth, Maine.

Recent—Gaspé; Labrador (Packard); also coast of New England.

I found, many years ago, a few specimens of this shell at a cove where a number of species of marine shells occur in Boulder-clay, and it was published in my list of shells from this place in my paper on the Post-pliocene of Labrador, Maine, &c. It is credited by Packard to "Zeeb's Cove," Cape Elizabeth, which may probably be the same place where I procured it. This species has not yet been found within the limits of Canada in the Post-pliocene, though this and the related species or variety, *M. solidissima*, are found living at Labrador. It has perhaps moved northward since the glacial period.

Mesodesma (*Ceronia*) *deaurata*, Turton.

Fossil—Matanne River (Bell.) I have not seen it in any other locality; and it occurs only on the lowest terrace, so that possibly it is modern.

Recent—Abundant at Tadousac and elsewhere in Gulf St. Lawrence; Labrador (Packard.)

This must be a modern species on our coasts; but according to Wood it is found in the Red Crag of England.

Venericardia (*Cardita*) *borealis*, Conrad.

Fossil—Labrador (Packard.)

Recent—Arctic seas to Long Island, and common throughout the Gulf of St. Lawrence. It would seem to have been much less generally distributed in the Post-pliocene. Western America as far south as Catalina Island. (P. P. C.)

Astarte Laurentiana, Lyell.

Fossil—Leda clay, Montreal, abundant; Beauport and Rivière-du-Loup, rare.

Recent—Greenland (Morch); Labrador (Packard); Murray Bay.

This shell may be a variety of the next species; but it is at least a very distinct varietal form. It is distinguished by its very fine and uniform concentric striation, passing to the ends of the valves and to the ventral margin. There are two varieties, a flatter, and more tumid. I have the former from Greenland named by Morch *A. Banksii*, and the latter named *A. striata*; but they are different from shells indicated by these names in Gould and elsewhere. The only recent specimens that I have seen from the Gulf of St. Lawrence, which can be referred to this species, are a few I dredged at Murray Bay. *A. Laurentiana* is very abundant at Montreal, but much more rare nearer the coast. It is evidently an Arctic form. (See Figure.)

Astarte Banksii, Leach.

Fossil—Leda clay, Rivière-du-Loup, abundant; Quebec, not infrequent; Montreal, very rare; Labrador (Packard); Portland, Maine, also Uddevalla, Clyde beds and Crag.

Recent—Abundant at Gaspé and elsewhere in Gulf of St. Lawrence, and also Arctic seas and coast of Nova Scotia.

This shell is that named *A Banksii*, in Gould's last edition, also in Beechey's voyages. It is easily distinguished from the last species by its coarser striation, fading toward the ends and also toward the margin of the shell. It is however about the same size, but less delicate and symmetrical in form. It is the common small Astarte of the Gulf St. Lawrence, and also of the Post-pliocene of Rivière-du-Loup; but becomes very rare at Montreal, where it is replaced by *A. Laurentiana*. This species was named *A. compressa* in my former lists, and it is certainly very near to European specimens of that species, especially to the fossils from the Clyde beds and the Crag. (See Figure.)

Astarte Elliptica, Brown.

Fossil—Labrador; Saguenay; Portland, Maine.

Recent—Labrador; Murray Bay; Gaspé; coast of Nova &c. Also Greenland; Norway (typical); Scotland.

Specimens from the Clyde beds are perfectly identical with ours. It is also found in the Post-pliocene of Norway and rarely

in the Crag. It is a northern species meeting on the American coast the closely allied forms *A. Undata* and *A. lens*, into which however it does not seem to pass. The two latter species, being more southern forms, are not found in the Post-pliocene.

A. Omalii of S. Wood from the Crag, is very near to this species, but is at least a distinct variety.

Astarte Arctica, Möller, (var *Lactea.*)

Fossil—Labrador (Packard); Portland, Maine; also Greenland, (Möller).

Recent—Gaspé; also Arctic seas; Norway (typical).

This species has not yet been found in the Post-pliocene of Canada, except in Labrador; and it seems to be a rare shell in the Gulf of St. Lawrence. It is our largest Astarte and I believe it to be identical with *A. borealis*, Chem., *A. lactea*, Brod. and Sow., and *A Semisulcata*, Gray. Fossil specimens from Portland, are precisely similar to recent ones from Gaspé dredged by Mr. Whiteaves, and referred by him to *A. lactea*. Specimens from Norway (*A. Arctica*) and from Clyde beds (*A. Borealis*) are smoother and less ribbed than ours.

Other species of Astarte.

At Murray Bay, there occurs very rarely a transversely elongated and regularly striated Astarte with delicately wrinkled epidermis, which seems to be identical with *A. Richardsonii* from the Arctic seas as described but not as figured by Reeve. It is not improbably a young state of *Astarte Arctica*. A similar species or variety occurs, but very rarely, fossil at Rivière-du-Loup. *A. sulcata* (undata), *A. lens*, *A. crebricostata*, *A. castanea*, and *A. quadrans* have not yet been found fossil, though the three former at least live in the Gulf of St. Lawrence.*

Cardium pinnulatum, Conrad.

Fossil—Leda clay, Lawlor's Lake, N.B.

Recent—Gulf St. Lawrence, and coast of Nova Scotia and New England.

---

* *A. undata* Gould and *A. quadrans*, Gould, certainly occur in the Gulf of St. Lawrence N. of the Bay of Chaleurs. A shell dredged in deep water N. of Anticosti may be *A. crebricostata*. *A. lens*, Stimpson, and *A. castanea*, Say, have not yet occurred to me in dredgings from more than 60 localities N. of New Brunswick. J. F. W.

Cardium Islandicum, Linn.

Fossil—Rivière-du-Loup; Murray Bay; Saguenay; Portland, Maine; Lawlor's Lake, N.B.; Greenland, Möller).

Recent—From Greenland to New England.

Our fossil specimens are mostly small, and similar to the northern variety or sub-species named by Stimpson *C. Hayseii*, and which also occurs living as far south as Nova Scotia, and seems to be the *C. ciliatum* of Fabricius. Decorticated specimens are not distinguishable from *C. Dawsonii* of Stimpson, from the Post-pliocene of Hudson's Bay; of which I have seen only specimens in this state.

Serripes Grœnlandica, Chemnitz.

Fossil—Leda clay, and Boulder clay, Quebec; Rivière-du-Loup; Murray Bay; Lawlor's Lake, N.B.; Cape Elizabeth, Maine; Labrador, (Packard); Greenland (Möller).

Recent—Gulf St. Lawrence, sometimes of large size, Arctic seas, and Greenland to Cape Cod.

This shell is somewhat rare and of small size in the Post-pliocene, and has not yet been found higher up the St. Lawrence than Quebec. Specimens of good size occur at Portland.

Cryptodon Gouldii, Philippi.

Fossil—Montreal, rare.

Recent—Murray Bay; Gaspé (Whiteaves); Greenland to New England.

The European form *C. flexuosa* is usually regarded as distinct, and is found as far north as Spitzbergen, and in the Crag, the Clyde beds, and the Norway Post-pliocene. Jeffreys, however, considers the difference merely varietal, and it certainly seems to diminish or disappear in the northern and glacial specimens.

According to Mr. Whiteaves this species has a great range in depth in the Gulf St. Lawrence, being found, living, from 20 to 300 fathoms.

Sphaerium?

Fossil—Pakenham Mills, with fresh-water bivalves and *Tellina Grœnlandica*. The specimens were too imperfect for certain determination.

Unio rectus, Lamarck.

Fossil—Clarenceville, Lake Champlain (Dickson), with *Mya arenaria*, *Tellina Grœnlandica*, &c.

Recent—River St. Lawrence.

Unio Cardium? Rafinesque.

Fossil—With the preceding. This and the preceding species were represented by large and thick shells better developed than those of the River St. Lawrence at present. It is probably the same with *U. ventricosus*, Say.

Mytilus edulis Linn.

Fossil—Montreal; Acton; Rivière-du-Loup; Quebec; Labrador (Packard); Lawlor's Lake, N.B. (Matthew); Greenland (Möller).

Recent—North Atlantic and Arctic seas generally; North Pacific (= *trossulus*, Gould) as far south as Monterey.

The variety most commonly found in the Post-pliocene is a small, oval, tumid form, allied to variety *elegans* of British writers (see figure). This variety still lives at Tadoussac; and is apparently characteristic of situations where the water is cold and exposed to intermixture of fresh water. The ordinary variety occurs at Portland, and also in some of the upper beds at Rivière-du-Loup. At Montreal only the small oval variety occurs. This variety is also found in the Clyde beds and in the crag.

Modiola modiolus, Linn.

Fossil—Montreal, very rare.

Recent—Labrador to New England; very common on the coasts of Nova Scotia and New England; North Pacific; found sparingly along the Vancouver and Californian coasts till it is replaced in the Gulf fauna by *M. capax*, Conrad.

This species becomes rare to the northward; and this, as well as its being proper to rocky shores rather than to clays and sands, may account for its rarity in the Canadian Post-pliocene. It is, however, common in the glacial beds of Europe.

Modiolaria nigra, Gray.

Fossil—Montreal; Rivière-du-Loup (small variety *nexa*; also large and fine); very large and well preserved in nodules at Kennebeck, Maine; Labrador (Packard of his *M. discrepans* as I suppose.)

Recent—Gulf of St. Lawrence (Whiteaves). Very large and fine on coast of Nova Scotia (Willis), and as far north as Greenland (*M. discors*, Fabricius).

Modiolaria corrugata, Stimpson.

Fossil—Rivière-du-Loup.

Recent—Murray Bay and Cacouna; precisely similar to the shells from the Post-pliocene. Also Greenland (Moller); Labrador (Packard); and south to Cape Cod.

Modiolaria discors, Leach.

Fossil—Beauport, of good size; Greenland (Möller).

Recent—Labrador to New England. Specimens from Gaspé are precisely similar to the fossil. This shell is no doubt identical with *M. lævigata* of Gray, and possibly with the *M. discrepans* of some other authors. It is however the same with that figured in Binney's Gould as *M. discors*.

Crenella glandula, Totten.

This species, which is at present quite common in the Gulf St. Lawrence, is indicated in my formerly published lists as a Montreal fossil; but I have mislaid the specimens, and cannot therefore now repeat the comparisons with the recent shells.

According to Mr. Whiteaves this is quite distinct from *C. decussata*, Montagu, both being found living in Gaspé.

Nucula tenuis, Montagu.

Fossil—Leda clay, Montreal; Saco (var. *inflata*); Rivière-du-Loup?

Recent—North shore Gulf St. Lawrence to Gaspé (Whiteaves) type and var. *inflata*; also European coasts.

N. expansa, Reeve.

Fossil—Leda clay and Boulder clay, Rivière-du-Loup; Saco; Duck Cove, St. John, N.B.

Recent—Labrador (Packard); Murray Bay; Arctic seas.

I doubt if this is not a large and well-developed northern form of *N. tenuis*.

N. antiqua, Mörch, from Leda clay of Maine, seems to be a variety.

Leda pernula, Muller.

Fossil—Leda clay, Rivière-du-Loup; Portland; Saco; Lawlor's Lake, N.B. (Matthew).

Recent—Arctic seas and south to New England.

This shell occurs very abundantly at Rivière-du-Loup; and the specimens found there show that no specific line can be drawn between the forms known as *pernula*, *buccata* (Steenst.),

tenuisulcata, Gould, and *Jacksonii*, Gould. Slender and flattened varieties are *pernula* and *tenuisulcata*, shorter and more tumid forms are *buccata;* and specimens decorticated so as to show the origin of the hinge teeth are *Portlandica*. Comparison of specimens from Greenland, Norway, Labrador, the Gulf St. Lawrence, and New England, confirms this conclusion. (See Figure.)

Leda minuta, Fabricius.

Fossil—Leda clay, Montreal; Rivière-du-Loup; Greenland (Möller); Labrador (Packard).

Recent—Arctic seas, Gulf St. Lawrence; coast of Nova Scotia.

The fossil specimens occur abundantly with the last species at Riviére-du-Loup, and are quite similar to those dredged at Murray Bay. This was called *L. caudata* in my former lists.

Lyda pygmæa, Munster.

Fossil—Leda clay. Green's Creek, Ottawa; Saco; Maine; also English Crag and other Glacial beds.

Recent—North European seas; but not yet recognized on the American coast. According to Mr. Jeffreys and Dr. Carpenter, our drift shells are referable to the variety or species *Yoldia abyssicola* of Torell.

Leda (Portlandia) glacialis, Gray; *truncata*, Brown.

Fossil—Leda clay and Boulder clay, Montreal; Quebec; Ottawa River; Rivière-du-Loup; St. John, N.B.; Portland and Saco, Maine; also in Post-pliocene of Norway (Sars), and of Scotland (Crosskey).

Recent—Arctic seas.

This shell is most abundant, and generally diffused in the Leda clay; and the variety ordinarily found at Montreal and Rivière-du-Loup is precisely identical with the ordinary Arctic form. A long variety, called *L. intermedia* by Sars, is also found at Montreal, though rarely. A short variety, common in the Post-pliocene at Murray Bay, is similar to the *L. siliqua* of Reeve from the Arctic seas; and young and depauperated varieties resemble *L. sulcifera* of the same author. The abundant material from the Post-pliocene shows that these are all varietal forms.

This shell is *Yoldia Arctica* of Sars, but not of Möller and Morch. It is *Y. truncata* of Brown. It is *Portlandia glacialis* of Gray, and *Leda Portlandica* of Hitchcock.

Yoldia lucida, Lovén (which is abundant living in the deeper parts of the Gulf of St. Lawrence) closely resembles the young, smooth form of this species, but I think the two may be distinct. J. F. W.

Leda (*Yoldia*) *limatula*, Say.

Fossil—Leda clay, Rivière-du-Loup.

Recent—Gulf St. Lawrence to Long Island.

This shell has been found as yet only at Rivière-du-Loup, where the specimens however are as good as those now living in the Gulf. (See Figure.) It will be observed, however, that though they have the number of teeth of *Y. limatula*, they approach in form to the allied species or variety *Y. sapotilla*, a shell which occurs in Greenland and thence to New England, and which I strongly suspect is merely a short variety bearing a similar relation to *Y. limatula* to that which *Mya Uddevallensis* bears to the ordinary *M. truncata*. *Y. sapotilla* is, I may mention, the *Y. Arctica* of Morch, as proved by a specimen from his collection now in my possession.

Leda (*Yoldia*) *myalis*, Couthuoy.

Fossil—Labrador (Packard).

Recent—Gaspé (Whiteaves) to south of Cape Cod. This shell is supposed to be identical with *N. hyperborea*, Lovén, from Spitzbergen.

Pecten Grœnlandicus, Chemnitz.

Fossil—Leda clay, Portland and Saco, Maine; not yet found in Canada.

Recent—Gulf St. Lawrence (Whiteaves) in deep water 200 to 300 fathoms.

This species is found in the Clyde beds and in Greenland; and if, as Jeffreys supposes, identical with *P. similis* (Laskey), it is a shell of very wide distribution in the Atlantic, as well as in geological time. Though not yet found in Canada as a Post-pliocene fossil, its occurrence as a fossil in Maine and recent in the Gulf St. Lawrence, renders it probable that it may yet occur in our Leda clays.

Pecten tenuicostatus, Mighels.

Fossil—Leda clay, St. John, N.B. (Matthew).

Recent—Labrador to Cape Cod.

This shell has not yet been found in the Post-pliocene of the

St. Lawrence valley; but since, according to Packard, it is common in Labrador, there is nothing remarkable in its occurrence in the Post-pliocene of St. John.

Pecten Islandicus, Chemnitz.

Fossil—Rivière du-Loup; Quebec; Labrador (Packard); St. John, N.B. (Matthew); Portland, Maine; Greenland (Möller); also Crag, Clyde beds, and Post-pliocene of Norway.

Recent—Gulf St. Lawrence, and from Greenland to Connecticut.

This is a shell which is very durable, and retains even its colour when imbedded in the clays. In this it excels the Tellinas, Astartes, Saxicava and Ledas; though these in turn are always much better preserved than the Mytili and Modiolæ.

Class III.—Gasteropoda.

Philine lineolata, Couthuoy.

Fossil*—Montreal, rare.

Recent—Gaspé; Grand Manan (Stimpson); Nova Scotia (Willis). It is *Philine lima*, Brown, according to Jeffreys.

Cylichna alba, Brown.

Fossil—Montreal; Rivière-du-Loup; also in the Clyde beds.

Recent—Gaspé; Labrador (Packard); Gulf St. Lawrence, common (Whiteaves); Arctic seas generally. Same or similar on West Coast at Sitka (P.P.C.)

Cylichna oryza, Totten.

Fossil—Montreal.

Recent—Coast of New England.

Cylichna nucleola, Reeve.

Fossil—Montreal; rare, and perhaps doubtful.

Recent—Arctic seas.

Cylichna occulta, Mighels and Adams.

Fossil—Montreal; Murray Bay; Maine.

Recent—Greenland to New England.

Cylichna striata, Brown.

Fossil—Rivière-du-Loup and Clyde beds.

Recent—Arctic seas.

---

* Except when otherwise stated, all the Gasteropods are found in the Leda clay, or at its junction with the Saxicava sand.

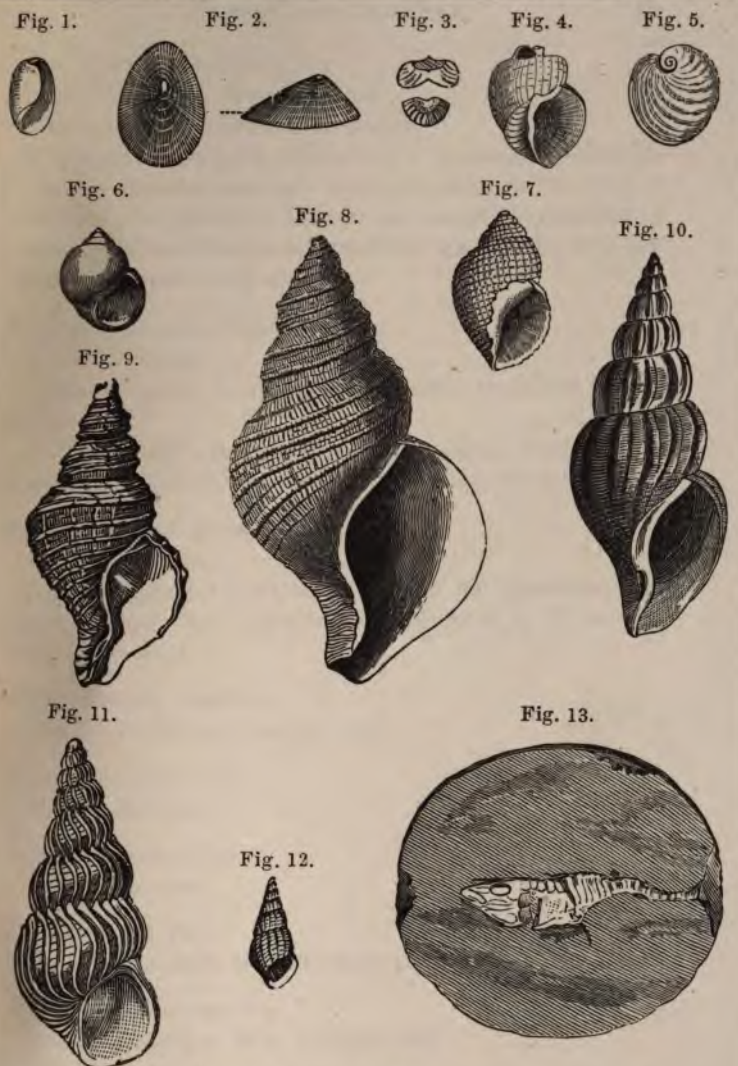


FIG.

1. *Haminea solitaria*, Montreal.
2. *Lepeta caca*, Montreal.
3. Plates of *Amicula Emersonii*, Montreal.
4. *Trichotropis arctica?* Montreal.
5. *Velutina zonata*, Montreal.
6. *Natica clausa*, Montreal.
7. *Admete viridula*, Montreal.

FIG.

8. *Fusus tornatus*, Montreal.
9. *Fusus tornatus* (Var.), Quebec.
10. *Sipho Kroyeri* (recent specimen, after Packard).
11. *Scalaria Grœnlandica*, Riviere-du-Loup.
12. *Acirsa Eschrichtii*, Quebec.
13. *Gasterosteus*, Green's Creek, Ottawa

Bulla (Haminea) solitaria, Say.

Fossil—Montreal; rather common.

Recent—New England and northward.

If this species is rightly determined, it furnishes a curious instance of a somewhat southern species occurring in the drift of Montreal. The *Hamineæ*, however, can scarcely be identified by weathered or fossil specimens, so that this may possibly be a northern form distinct from *solitaria*.

Bulla (Diaphana) debilis, Gould.

Fossil—Montreal.

Recent—Gulf St. Lawrence (Whiteaves); Greenland to New England.

Jeffreys considers it the same with *B. hyalina*, Turton. If so, it is a shell of the Clyde beds and of the Arctic seas generally.

Bulla (Utriculus) pertenuis, Mighels.

Fossil—Montreal.

Recent—Labrador (Whiteaves); Gulf St. Lawrence, and south to Cape Cod. According to Jeffreys it is *U. turritus*, Möller, Greenland.

Helix striatella, Anthony.

Fossil—Pakenham, Saxicava sand.

Lymnea umbrosa, Say.

Fossil—Montreal.

Lymnea caperata, Say.

Fossil—Montreal.

Lymnea elodes, Say.

Fossil—Pakenham Mills, Saxicava sand.

Planorbis bicarinatus, Say.

Fossil—Pakenham Mills, Saxicava sand.

Planorbis trivolvis, Say.

Fossil—Pakenham Mills, Saxicava sand.

Planorbis parvus, Say.

Fossil—Pakenham Mills, Saxicava sand.

All of the above pulmonates are modern Canadian species, and seem to have been drifted by some fresh-water stream into the sea of the Saxicava sand and Leda clay.

Siphono-dentalium vitreum, Sars.

Fossil—Leda clay, Murray Bay; also Norway (Sars).

Recent—Gulf of St. Lawrence (Whiteaves); coast of Norway (Sars.) It is a rare deep-water shell.

Amicula Emèrsonii, Couthuoy.

Fossil—Montreal.

Recent—Murray Bay; Halifax; coast of New England.

My specimens are merely detached valves. They indicate an animal quite similar to specimens from Halifax referred to this species, but differ slightly from specimens from Murray Bay. Dr. Carpenter has labelled the drift form var. "*altior*." The differences among the recent specimens, as well as the fossil valves, will be discussed in the "Contributions to a Monograph of the Chitonidæ," about to be printed by the Smithsonian Institution.

Puncturella (*Cemoria*) *Noachina*, Linn.

Fossil—Quebec; Rivière-du-Loup; Clyde beds.

Recent—Gulf St. Lawrence generally; and throughout the Arctic seas and North Atlantic.

Acmæa testudinalis, Möller.

Fossil—Labrador.

Recent—Gulf St. Lawrence generally; and throughout the Arctic seas and North Atlantic.

My only fossil specimen, obtained from Dr. Packard, is of the small, elevated and depauperated variety so common at Murray Bay and the north shore of the Gulf. It is curious that this common modern species is so very rare in the Post-pliocene.

Lepeta cœca, Möller.

Fossil—Montreal; Riviére-du-Loup; Quebec; Labrador; European Post-pliocene.

Recent—Gaspé; Labrador; Arctic seas generally; and coast of New England rarely.

This shell is not at all rare, living at Gaspé, and fossil at Rivière-du-Loup. Carpenter remarks that some of my Montreal specimens have the characters of variety *striata* of Middendorff from Siberia.

Capulus commodus, Middendorff.

Fossil—Point Levi, near Quebec. One specimen only, found by Mr. Gunn and communicated by Dr. W. J. Anderson.

Recent—Scotland (Jeffreys).

This species is fossil at Uddevalla, and is supposed to be the same with *C. fallax* and *C. obliquatus* of Wood from the English Crag. It has not yet been recognized on the American coast. (See Figure.)

Margarita helicina, Fabricius.

Fossil—Montreal; Murray Bay.

Young specimens resemble *M. acuminata* of Mighels. Broad specimens resemble *M. campanulata*, Morse.

Recent—Arctic seas; Gulf of St. Lawrence; and coast of New England. It is *M. Arctica*, Leach.

Margarita argentata, Gould.

Fossil—Montreal, rare.

Recent—Labrador and Gulf St. Lawrence (Whiteaves); Murray Bay; Gaspé; coast of New England and Nova Scotia? Possibly the same with *M. glauca*, Möll., from Greenland.

Margarita cinerea, Couthuoy.

Fossil—Rivière-du-Loup, Portland.

Recent—Gaspé; Labrador; Greenland to New England; var. *striata*, Dall, Sitka.

Cyclostrema (*Mölleria*) *costulata*, Möller.

Fossil—Montreal; Clyde beds; Uddevalla.

Recent—Gaspé; Arctic seas to New England.

Cyclostrema Cutleriana, Clark.

Fossil—Montreal, rare.

This is an Arctic and British shell, as yet recognized only at Montreal.

Turritella erosa, Couthuoy.

Fossil—Labrador; Rivière-du-Loup; Montreal?

Recent—Greenland to New England.

Turritella reticulata, Mighels.

Fossil—Labrador (Packard).

Recent—Labrador to Gulf St. Lawrence; also fishing banks, Nova Scotia (Willis).

My specimens received from Dr. Packard are marked *T. costulata*, but seem rather to be the above species.

Turritella acicula, Stimpson.

Fossil—Rivière-du-Loup; Labrador (Packard).

Recent—Murray Bay; coast of New England.

There may be some reason to donbt whether this is not a variety of *T. erosa*. It is quite possible that the above species should be regarded as *Mesaliæ*.

Paludina (*Melantho*) *decisa*, Say.

Fossil—Pakenham Mills, Saxicava sand.

Recent—Eastern America generally.

Valvata tricarinata, Say.

Fossil—Pakenham Mills, with the preceding.

Recent—Eastern America generally.

Amnicola limosa, Say.

Fossil—Pakenham Mills, with the preceding.

Recent—Hudson's Bay to Virginia.

This was *A. porata* of the previous lists.

Littorina rudis, Donovan.

Fossil—Rivière-du-Loup; also Clyde beds and Uddevalla.

Recent—Arctic seas to New England and European coasts.

L. tenebrosa, which may be regarded as a variety, is also found at Rivière-du-Loup.

Rissoa castanea, Möller.

Fossil—Montreal.

Recent—Gaspe; Labrador; Trinity Bay (Whiteaves).

Rissoa exarata, Stimpson.

Fossil—Montreal.

Recent—New England.

Rissoa scrobiculata, Möller.

Fossil—Montreal.

Recent—Greenland; Gulf St. Lawrence, 200 to 300 fathoms, large; and small, Gaspé, 30 fathoms (Whiteaves).

Bela harpularia, Couthuoy.

Fossil—Montreal; Quebec; Murray Bay; Rivière-du-Loup (large specimens).

Recent—Gulf St. Lawrence; very fine at Murray Bay, and similar to large specimens from Rivière-du-Loup; coast of New England. It is *B. Woodiana*, Möller (J. F. W.)

Bela elegans, Möller.

Fossil—Montreal.

Recent—Greenland and Norway; closely allied to next species.

Bela pyramidalis, Ström.

Fossil—Montreal; also Crag, Clyde beds and Uddevalla.

Recent—Labrador (Packard); Gulf St. Lawrence (Whiteaves); Murray Bay, and south to Cape Cod; Arctic seas generally. It is the *B. pleurotomaria* of Couthouy. and *B. Vahlii* of Beck.

Bela turricula, Montagu.

Fossil—Montreal; Rivière-du-Loup; Labrador; also Red Crag and Uddevalla (Jeffreys).

Recent—Gulf of St. Lawrence and coast of Nova Scotia and New England.

I include under this name *B. nobilis* of Möller; *B. Americana*, Packard; *B. scalaris*, Möller; *B. exarata*, Muller, Morch; and *B. angulata*, Reeve. The var. *nobilis* is found at Montreal and Gaspé; also young shells not distinguishable from *exarata*. Var. *scalaris*, occurs at Rivière-du-Loup and Labrador. This shell is a widely diffused and somewhat variable northern species. Mr. Whiteaves, however, regards *B. nobilis*, *B. exarata*, and *B. scalaris* as distinct.

Bela Trevelliana, Turton.

Fossil—Rivière-du-Loup; Labrador; also Clyde beds and Norway (Jeffreys).

Recent—Murray Bay; Arctic seas, and Greenland to Massachusetts. It is probably *B. decussata* of Couthuoy. *B. excurvata* from Puget Sound, may prove another variety.

Bela violacea, Mighels and Adams.

Fossil—Montreal.

Recent—Murray Bay; Labrador (Packard); Gaspé (Whiteaves; Fishing banks Nova Scotia (Willis); Massachusetts (Stimpson).

Bela cancellata, Mighels and Adams.

Fossil—Murray Bay; Labrador (Packard); Casco Bay (Gould). This shell may be *B. impressa*, Beck. In any case the fossils are identical with the modern Murray Bay specimens. It also occurs living in Gaspé Bay (Whiteaves).

Natica affinis, Gmelin.

(*Natica clausa*, Brod. and Sowerby.)

Fossil—Montreal; Quebec; Rivière-du-Loup; Labrador; Portland, Maine.

Recent—Greenland to Cape Cod.

Common and extensively distributed in the Post-pliocene of Europe, from Norway to Sicily, and found at an elevation of 1330 to 1360 feet in Moel Tryfaen, Wales. (Darbyshire).

Lunatia heros, Say.

Fossil—Beauport, a single specimen only, and this of small size.

Recent—Labrador and southward.

This species is as old as the Miocene Tertiary; and in the Post-pliocene, Canada was probably its extreme northern limit.

Lunatia Grœnlandica, Beck.

Fossil—Montreal; Quebec; Rivière-du-Loup; Maine; also Post-pliocene of England, Scotland, and Norway.

Recent—Arctic seas generally; and extending to Britain and New England.

L. pallida is the representative of this species on the west coast of America.

Choristes elegans, Cpr.

Fossil—Saxicava sand, Montreal, rare.

This shell was identified in my former papers with *Natica helicoides;* but it is now found to be quite distinct, and Dr. P. P. Carpenter describes it as a new species and genus as follows:

Genus CHORISTES.

Testa helicoidea, tenuis; epidermide induta; anfractus disjuncti; labrum postice angulatum, antice haud emarginatum; labium planatum; columella simplex. Animal ignotum.

Choristes elegans, n. s.

Ch. t. satis elevatâ, tenui, nitente; epidermide fulvâ, tenui, lævi, extus et intus omnino appressâ; anfr. iii. + ...?, vertice nucleoso decollato, spiraliter obsoletius striatis; lineis incrementi tenuissimis; spirâ superne planatâ, suturis maxime impressis, basi tumente; umbilico intus majore, extus modico; aperturâ sublunatâ, postice ad angulum circ. 30° inclinatâ, antice late rotundatâ; labro acuto, postice planato; labio acuto, planato, haud reflexo; columellâ postice regulariter arcuatâ, neque emarginatâ, nec angulatâ, nec insculptâ.

Long. (apice decollato) ·82, *long. spir.* ·32, *lat.* ·76. poll. *Div.* 90°.

Hab. Montreal, in strato glaciali, fossilis, rarissime reperta. Mus. Dawson, McGill Coll., Nat. Hist. Soc.

Dr. Carpenter adds the following remarks:

While almost all the other drift fossils are of species still living in the neighbouring seas, this is not known, even generically, to be at present in existence. It is hard to pronounce satisfactorily on its relationships. In its thin, coated shell it resembles Velutina; the striæ and loose whirls recall Naticina; the straight pillar lip reminds us of Fossarus; while the umbilicus and rounded base, with entire mouth, best accord with the Natica group. With Trichotropis and its congeners I can see no resemblance. One remarkable feature in all the specimens is the decollation of the upper whirls, seen even in a nearly perfect young specimen, ·2 across; other young specimens, even smaller, have only one whirl and a half remaining. The broken portion is filled up not so much by a septum as by a solid thickening. The separation of the whirls is complete from the beginning; and although, in the parietal portion, they are closely appressed, the smooth and somewhat glossy epidermis is distinctly seen between. The fracture of the mouth in most of the specimens, enables this feature to be distinctly observed; and would also reveal the "internal groove" and columellar callosity ascribed to Torellia, did any such exist.

The straightening of the inner lip, at an angle of 30° from the axis, makes the umbilicus by no means large (for a Naticoid shell) when viewed from the base in the line of the pillar; but the same cause enlarges it within, recalling the adult appearance of Amphithalamus. The flattening of the upper portion of the whirls gives the shell somewhat of an Ianthinoid aspect.

While the analogies of the shell point in so many different directions, it is impossible to assign it even to its family group. It is to be hoped, however, that the dredge will yet reveal its existence in a living state.

The above species may be supposed to resemble *Torellia vestita*, Jeffreys, from Norway. Our specimens differ however in form, as above noted, and also in the absence of the tooth in the inner lip, and in the smooth epidermis.

The shell in question presents the very unusual character of having the whirls appressed, yet quite disconnected; the smooth

epidermis lining the umbilical chambers, and conspicuously preserved, even in these fossil specimens, between the closest parts of the parietal region. In this respect it bears the same relation to Torellia as does Latiaxis to Rapana, Separatista to Rhizochilus, or Zanclea to Torinia. It presents a rude resemblance to Separatista Chemnitzii (Add. Gen. pl. xiv. f. 6), or still more to S. Blainvilleana (Chènu Man. p. 172, § 853), but without the grooved pillar, or the keels of the latter species.

As to the "blunt tubercle" or "callous protuberance" of Torellia, described by Mr. Jeffreys, but scarcely to be traced in Mr. Sowerby's figure, it certainly does not exist in our fossils. It is not always a character of importance, as may be seen by comparing Purpura columellaris with P. patula, Cuma tectum with the remaining species of the genus, or the gradual transition from Isapis to Fossarus. The Naticidæ are often very irregular in the callous region of the pillar, even in the same species.

Velutina zonata, Gould.

Fossil—Montreal; Beauport.

Recent—Arctic seas to Massachusetts.

According to Jeffreys, this shell is the same with *V. undata*, Smith, from the Clyde beds, and is found in the Crag and in the Post-pliocene of Uddevalla.

Scalaria Grœnlandica, Perry.

Fossil—Rivière-du-Loup; Quebec; Saco; also Scottish Post-pliocene and English Red Crag, under same varietal forms as in Canada.

Recent—Arctic seas, and American coast, as far south as Massachusetts.

The specimens from Rivière-du-Loup are very large, one being nearly two inches long; and, as Dr. Beck has remarked, the varices of some of the specimens are more slender and lamellar than in recent specimens, others, however, are similar to the more common recent variety.

Acirsa Eschrichtii, Holboll.

Fossil—Quebec; Rivière-du-Loup; Montreal; most abundant at Rivière-du-Loup.

Recent—Murray Bay; Greenland; also Eastport (Verrill.)

This shell was named in former papers *Menestho albula*, the eroded specimens found being referred to that species. It has,

however, been correctly described by Dr. Beck in Lyell's paper on Beauport, and named *Scalaria borealis*. It is not this species of Gould, however.

Trichotropis borealis, Brod. and Sow.

Fossil—Montreal; Rivière-du-Loup; Labrador, &c.; very abundant at Montreal.

Recent—Labrador, Murray Bay, Gaspé, Arctic seas, and as far south as Massachusetts.

Trichotropis arctica? Middendorff.

Fossil—Montreal, very rare.

A single imperfect specimen represents this species, which is recent at Behring's Straits. The identification is perhaps doubtful.

The figure given by Reeve of *T. Kenseri* of Phillippi from Spitzbergen, resembles our shell, except in the small number of revolving bands.

Admete viridula, Fabricius.

Fossil—Montreal.

Recent—Labrador, (Packard); Murray Bay; Gaspé, (Whiteaves); also Greenland and Labrador. It is the *Tritonium viridulum* of Fabricius, and is a rare shell in the Canadian Post-pliocene, and in the Gulf of St. Lawrence.

Aporrhais occidentalis, Beck.

Fossil—Labrador (Bayfield); also Packard.

Recent—Labrador to Massachusetts.

It is remarkable that this species, which is found living from Labrador to Cape Cod, is so rare in the Post-pliocene.

Fasciolaria ligata, Mighels.

Fossil—Montreal, very rare.

Recent—Murray Bay; Mingan (Foote); Gaspé, (Whiteaves); Nova Scotia, (Willis); rare in all these localities.

A single mutilated specimen alone, as yet, represents this species in my Post-pliocene collections.

Astyris Holbollii, Möller.

Fossil—Rivière-du-Loup; also glacial beds Britain (Jeffreys).

Recent—Gaspé; Murray Bay; Labrador, (Whiteaves). If identical, as I suppose, with *Columbella rosacea*, Gould, it extends south to New England, and Gould's name has priority.

Buccinum undatum, Linn.

var. *undulatum*, Möller.

var. *Labradoricum*, Reeve.

Fossil—Saxicava sand and Leda clay, Rivière-du-Loup; Labrador; Duck Cove, St. John, N.B.; Maine (Packard).

Recent—Gulf St. Lawrence; south Greenland to Nantucket. (See Figure.)

I cannot satisfy myself that there is any good specific distinction between this shell and *B. undatum* of the European seas and glacial beds. It varies very much in size, in slenderness, in the fineness of the spiral striation, in the development of the ribs, in the extension of the mouth, and in the thickness of the shell. The coarser forms are *B. Labradoricum*, which passes into the ordinary *undatum*. Medium varieties are *B. undulatum*, and smooth varieties pass into *B. cyaneum* and *B. Tottenii*, which last is the *ciliatum* of Gould.

Buccinum Tottenii, Stimpson.

Fossil—Rivière-du-Loup, Saxicava sand and Leda clay.

Recent—Murray Bay and Tadoussac; also Newfoundland Banks. It has some resemblance to *B. Humphreysianum*, Bennet, but is specifically distinct. It is the *B. ciliatum* of Gould, but has no connection with the *ciliatum* of Fabricius, except a slight resemblance to the smoother forms of the latter. It is remarkable for its very regular spiral lines, absence of folds and convex whirls.

Buccinum cyaneum, Bruguière.

Fossil—Rivière-du-Loup, abundant.

Recent—Murray Bay and Tadoussac; deeper parts of Gulf St. Lawrence (Whiteaves); Arctic seas.

This species or varietal form is well represented in the Figure, which is taken from a large Rivière-du-Loup specimen. Being on the one hand very near to if not identical with the smooth varieties of *B. undulatum*, and on the other resembling *B. Grœnlandicum*, it has received many names. It is believed to be *B. boreale* of Leach, and *Grœnlandicum* of Morch. It is a very characteristic northern form. (See Figure.)

Buccinum Grœnlandicum, Chemnitz.

Fossil—Leda clay and Boulder clay, Montreal; St. Nicholas; Rivière-du-Loup.

Recent—Greenland. Specimens from Morch are identical

with our fossils. This species is probably the *B. undatum* of Fabricius. It is allied to *B. cyaneum*, and may possibly pass into it. (See Figure.)

Buccinum tenue, Gray.

Fossil—Rivière-du-Loup, not uncommon; Greenland (Hayes); Labrador (Packard).

Recent—Murray Bay; Gaspé; Labrador (Packard); Arctic seas generally. A common Arctic species, but rare living in the Gulf, though much more plentiful in the Post-pliocene beds. (See Figure.)

Buccinum ciliatum, Fabricius.

Fossil—Montreal; Rivière-du-Loup.

Recent—Murray Bay; Greenland (Fabricius) to Nova Scotia (Willis).

This is the original *B. ciliatum* of Fabricius, and has been recognized as such by Dr. Stimpson. It is easily distinguished by its narrow Nassa-like mouth, armed with a tooth on the front of the pillar lip. It varies much in sculpture, especially in the longitudinal ribs. The variety found at Montreal is only slightly ribbed. That at Rivière-du-Loup is more distinctly ribbed, thus resembling the recent specimens from Murray Bay. It is quite distinct from *B. ciliatum*, Gould, which is very near the smoother varieties of *B. undulatum*. As it is a rare and little known shell, I have figured two extreme varieties, a fossil specimen from Montreal and a recent from Murray Bay.

Buccinum glaciale, Linn.

Fossil—Rivière-du-Loup; Montreal; Labrador; (Packard.)

Recent—Murray Bay; Greenland, and Arctic seas generally.

This shell has the aperture somewhat like that of *ciliatum* and a very peculiar sculpture of spiral striæ with intervening bands marked with finer striæ. It has also a carina angulating the body whirl, and sometimes more than one. In the latter case it passes into *B. Grœnlandicum*, Hancock (not Chemnitz) or *B. Hancocki* Morch. The ordinary variety is most common in the Modern Gulf, the latter in the Arctic seas and in the Post-pliocene. This shell, usually much decorticated, is the most common Buccinum in the Post-pliocence of Montreal. It was called *B. undatum* in previous lists.

Buccinum plectrum, Stimpson.

Fossil—Rivière-du-Loup; rare.

Recent—Murray Bay; Portland, Maine, (Stimpson); Behring's Straits, (Stimpson)

This may be a variety of the preceding species, but can be distinguished from it and grows to a larger size. It has the sculpture of *B. glaciale* with the aperture of *B. undulatum*. Recent and fossil specimens are quite similar.

The northern *Buccina* are involved in so much confusion that I have made them a subject of special study, and have sedulously collected all the forms recent and fossil. I have been very much aided in this by the abundance of specimens of the more Arctic forms at Rivière-du-Loup, and the the occurrence of most of them recent at Murray Bay and Tadousac, and I feel confident that the names given in this list represent forms actually occurring as distinct in nature, though some of them may not be distinct specific types. I believe, however, that *B. ciliatum* *B. glaciale*, *B. undatum*, *B. tenue* and *B. Grœnlandicum*, are probably entitled to this rank. The others appear to me on comparison of large numbers of specimens, to graduate into one or other of the above forms.

I have given in the engraved plate representatives of the more critical forms, which will enable them to be recognized.

In the drift the Buccinums often part with their outer coat of prismatic shell, and in this decorticated state are very difficult to determine.

Buccinofusus (*Sipho*) *Kroyeri*, Möller.

Fossil—Rivière-du-Loup; Labrador (Packard).

Recent—Gulf St. Lawrence and Arctic seas. First recognized as this species by Mr. Whiteaves. Specimens from Spitzbergen in Mr. McAndrew's collection are perfectly similar to ours. Packard found it not uncommon at Labrador, but it seems rare in other parts of the Gulf of St. Lawrence. In some previous lists it has appeared as *B. cretaceum*, Reeve, which seems to be an error.

Chrysodomus Spitzbergensis, Reeve.

Fossil—Montreal (small and rare.)

Recent—Murray Bay to Gaspé; also Spitzbergen, and probably Sea of Okotsk.

Only one specimen occurred at Montreal, and was an unknown

form until I fortunately dredged a few specimens at Murray Bay. It is a beautiful species, evidently quite distinct from *C. Islandicus*. From Middendorff's description and figure, I think it not improbable that it may be the same with his *Tritonium Schantaricum*, from the Sea of Okotsk. I was not aware that it had been found on our coast, except at Murray Bay, until these sheets were going through the press. Young specimens are remarkably like in form and sculpture to *Fasciolaria ligata*, which is found with it at Murray Bay. Reeve's figure in Belcher's "Last of the Arctic Voyages," well represents our specimens, though perhaps a very little coarser in sculpture.

Chrysodomus tornatus, Gould.

Fossil—Montreal; Quebec; Rivière-du-Loup; Murray Bay; Labrador (Packard).

Recent—Gaspé Bay, large specimens (Whiteaves; Labrador (Packard).

This shell is not uncommon in the drift, and owing to its dense texture is generally in good preservation. It ranges from the typical *C. tornatus* of Gould to *Fusus despectus* of Linnæus, as described by Fabricius, from Greenland, and shells of similar form from the British Crag are considered by S. Wood as varieties of *F. antiquus*.* Dr. P. P. Carpenter thinks that this and the British *F. antiquus* may prove to belong to one very variable species. The *C. despectus* is an Arctic form, and is found fossil in Canada. The *C. tornatus* is also fossil, and is the form now found in the Gulf. *C. decemcostatus* is more southern.

Chrysodomus decemcostatus, Say.

Fossil—Portland, Maine.

Recent—Magdalen Islands and Gaspé Bay (Whiteaves); coasts of Nova Scotia and New England.

This species has not yet been found in the Post-pliocene of Canada, where it is represented by *C. tornatus*. There are still two opinions as to whether Say's species is identical with *C. lyratus*, Mart. = *Middendorffii*, Cooper, from the Pacific coast. The latter is variable, and graduates towards *tornatus*, Gould, but the living New England shells are tolerably constant in character.

* The *C. despectus* of Reeve, however, is a very different species, from the Arctic regions of the North Pacific.

Trophon scalariforme, Gould.

Fossil—Montreal; Murray Bay; Rivière-du-Loup; Labrador.

Recent—Greenland (Hayes); Murray Bay; Nova Scotia (Willis); Gaspé and North Shore (Whiteaves).

It is a rare shell in the Post-pliocene, but of large size and in good condition.

Trophon clathratus, Linn.

Fossil—Montreal; Murray Bay; Rivière-du-Loup; also glacial beds of Europe.

Recent—Greenland and Arctic seas generally; Labrador; Gulf St. Lawrence (Whiteaves). The allied species or variety, *T. gunneri*, has been found living at Gaspé by Whiteaves, but not fossil as yet.

SUB-KINGDOM ARTICULATA.

Class I.—Annulata.

Serpula vermicularis, Linn.

Fossil—Montreal; Murray Bay; Rivière-du-Loup.

A small species of Serpula, apparently the above, though perhaps the determination may be regarded as uncertain.

Vermilia serrula, (Stimpson.)

Fossil—Rivière-du-Loup, on shells.

Recent—Gulf St. Lawrence. It is quite likely the Greenland species identified by Fabricius with *Serpula triquetra*.

Spiochætopterus typus, Sars.

Fossil—Labrador, (Packard).

Recent—Labrador (Packard); Norway (Sars.)

Spirorbis glomerata, Muller.

Fossil—Rivière-du-Loup; Labrador (Packard); Greenland (Fabr.); Gaspé.

Spirorbis vitrea, Fabricius.

Fossil—Montreal; Quebec; Rivière-du-Loup; Murray Bay Very common on stones and shells.

Recent—Greenland (Fabricius); Gulf St. Lawrence.

Spirorbis Spirillum, Lin.

Fossil—Rivière-du-Loup, on shells.

Recent—Gulf St. Lawrence; Greenland; Fabricius.

Spirorbis sinistrorsa, Montague.

Fossil—Rivière-du-Loup, on the inside of shells.

Recent—Gulf St. Lawrence; Fishing Banks, American Coast (Gould.)

Spirorbis carinata, Montague.

Fossil—Rivière-du-Loup, on shells.

This is a Spirorbis with one carina, found also in the Gulf of St. Lawrence, and possibly the same with the *S. contortuplicata* of Fabricius from Greenland.

The beautiful *Spirorbis cancellata* of Fabricius, so common in the Modern Gulf of St. Lawrence, and also in Greenland, has not yet been found in the Post-pliocene.

Class II.—Crustacea.

The most abundant species are bivalve Entomostraca, which occur in great numbers in the Leda clay, associated with Foraminifera. The species in my collection have been kindly determined by Mr. J. S. Brady, who enumerates the following:

Cythere MacChesneyi, nov. sp.
" *Dawsoni* (Brady).
" *globulifera* (Brady).
" *Logani*, nov. sp.
Cytheridea papillosa (Bosquet).
" *punctillata* (Brady).
Cytheridea Sorbyana (Jones).
Cytherura Robertsoni (Brady).
Cytheropteron complanatum, nov. sp.
" *inflatum* (B., C., and R., MS.)
" *angulatum* (B., C., and R., MS.)
Eucythere argus.

As the paper was re-printed in the *Canadian Naturalist* (Vol. V., N.S.) it is unnecessary to notice these species further here, except to state that out of twenty-nine species of recent Ostracods obtained by Mr. Brady from material from the Gulf St. Lawrence, furnished by me, thirteen have been recognized in the Post-pliocene of Canada and Maine, though only three of these occur in the list above given. It is further remarkable that out of thirty-three fossil species from Maine and Canada, no less than twenty-three occur in the Scottish glacial beds and twenty-five are living in the British seas, while six are new species.

Balanus Hameri, Ascanius.

Fossil—Montreal; St. Nicholas; Quebec; Rivière-du-Loup; also, Uddevalla; Russia (Murchison); Greenland (Spengler).

Recent—Coast of Nova Scotia. I have obtained specimens from Mr. Downes of Halifax, but have not elsewhere seen the species recent. It is *B. Uddevallensis* of lists of Scandinavian fossils and *B. tulipa* of Muller. It is a widely diffused Arctic and North Atlantic species.

This Acorn-shell is very abundant at Rivière-du-Loup, and fine specimens are found entire, attached to stones and boulders in the Boulder-clay.

Balanus porcatus, DaCosta.

Fossil—Beauport; glacial beds of Europe.

Recent—Gulf St. Lawrence, and coast of New England; Labrador (Packard); and Arctic and northern seas generally. It is no doubt *Lepas balanus* of Fabricius from Greenland.

Much more rare in the Post-pliocene than the preceding species.

Balanus crenatus, Brug.

Fossil—Montreal; Quebec; Rivière-du-Loup; St. John, N.B. (Matthew); Labrador (Packard); Portland, Maine; glacial beds of Europe.

Recent—Arctic and northern seas, Greenland; Gulf St. Lawrence and American coast. It seems to be *Lepas balanaris* of Fabricius, Greenland.

Eupagurus Bernhardus? Fabricius.

Fossil—Rivière-du-Loup. A small specimen in a *Turritella* may be the young of this common species.

Hyas coarctata, Leach.

Fossil—Riviére-du-Loup. A few claws only found, but evidently of this common Gulf of St. Lawrence species.

SUB-KINGDOM VERTEBRATA.

The vertebrate animals of the Post-pliocene are few, and may be summed up as follows:

Mallotus villosus, Cuvier.

The common capelin is found in nodules at Green's Creek on the Ottawa.

Cyclopterus lumpus, Linn.

The lump sucker occurs in nodules at the same place.

Gasterosteus.

In nodules at the same place, found by Sheriff Dickson. It closely resembles the two-spined stickleback of the Gulf St. Lawrence, but is not sufficiently perfect for description.

Vertebrae and other fragments of fishes not determinable, have been found at Rivière-du-Loup, and a bird's feather in a nodule on the Ottawa.

The Mammalia are represented in the marine Post-pliocene of Canada by *Phoca Grœnlandica*, Muller, found in the Leda clay at Montreal, and *Beluga Vermontana* in the same situation, and also in the Saxicava sand at Cornwall (Billings). The latter I believe to be identical with the modern *Beluga* of the Gulf St. Lawrence.

In the superficial gravels of Ontario, probably more recent than the marine beds, remains of a fossil elephant, *Euelephas Jacksonii*, have been found, and have been described by Mr. Billings (Can. Nat. vol. VIII).

FOSSIL PLANTS.

The only locality where fossil plants in any considerable number have been obtained, is at Green's Creek on the Ottawa, where they owe their preservation to the nodules of calcareous matter that have enclosed delicate specimens which otherwise could not have been secured from the soft Leda clay in which the nodules are enclosed. In addition to specimens collected by myself, I have examined the collections made by the late Rev. Mr. Bell of L'Original, those of the late Sheriff Dickson, and those of the Geological Survey. The whole were described in my paper in the Canadian Naturalist for February, 1866, and since that time no new material of importance has come into my hands. The species recognized are:

Drosera rotundifolia, Linn.
Acer spicatum, Lamx.
Potentilla Canadensis, Linn.
Gaylussacia resinosa, Jones.
Populus balsamifera, Linn.

Thuja occidentalis, Linn. (found at Montreal.)
Potamogeton perfoliatus, Linn.
Equisetum scirpoides, Michx.
Carices and *gramineæ*, fragments.
Fontinalis, sp.
Algae.

These plants occur in the marine Leda clay, containing its characteristic fossils, and were probably washed from the neighbouring land by streams. They indicate to some extent the flora of the Laurentian hills bordering the valley of the Ottawa, at the time of the Post-pliocene subsidence. The inferences as to climate deducible from them are stated in the following extract from the paper above referred to:

"None of the plants above mentioned are properly Arctic in their distribution, and the assemblage may be characterized as a selection from the present Canadian flora of some of the more hardy species having the most northern range. Green's Creek is in the central part of Canada, near to the parallel of 46°, and an accidental selection from its present flora, though it might contain the same species found in the nodules, would certainly include with these, or instead of some of them, more southern forms. More especially the balsam poplar, though that tree occurs plentifully on the Ottawa, would not be so predominant. But such an assemblage of drift plants might be furnished by any American stream flowing in the latitude of 50° to 55° north. If a stream flowing to the north it might deposit these plants in still more northern latitudes, as the McKenzie River does now. If flowing to the sonth it might deposit them to the south of 50°. In the case of the Ottawa, the plants could not have been derived from a more southern locality, nor probably from one very far to the north. We may therefore safely assume that the refrigeration indicated by these plants would place the region bordering the Ottawa in nearly the same position with that of the south coast of Labrador fronting on the Gulf of St. Lawrence, at present. The absence of all the more Arctic species occurring in Labrador, should perhaps induce us to infer a somewhat more mild climate than this."

The climatic indications afforded by these plants are not dissimilar from those furnished by a consideration of the marine fauna of the period of the Leda clay.

Addenda to Echinodermata.

Mr. T. Curry of Montreal has been so fortunate as to find in the Leda clay near that city, in addition to fragments apparently of an *Ophioglypha*, a specimen probably of *Ophiacantha spinulosa*, Muller and Tr., and one of *Solaster papposa*, Linn. Both of these are species now found in the Gulf of St. Lawrence. Mr. Matthews has also obtained a second species of Ophiurid Starfish at St. John.

Summary of Fossils.

The above lists include, in all, about 205 species, being more than twice the number included in previous lists, and distributed as follows:

Plants		10
Animals—Radiata		24
	Mollusca	140
	Articulata	26
	Vertebrata	5
		205

The whole of these, with the three or four exceptions, may be affirmed to be living Northern or Arctic species, belonging in the case of the marine species, to moderate depths, or varying from the littoral zone to say 200 fathoms. The assemblage is identical with that of the northern part of the Gulf of St. Lawrence and Labrador Coast at present, and differs merely in the presence or absence of a few more southern forms now present in the Gulf, especially in its southern part, where the fauna is of a New England type, whereas that of the Post-pliocene may be characterized as Labradorian. As might have been anticipated from the relations of the Modern marine fauna, the species of the Canadian Post-pliocene are in great part identical with those of the Greenland seas and of Scandinavia, where, however, there are many species not found in our Post-pliocene. The Post-pliocene fauna of Canada is still more closely allied to that of the deposits of similar age in Britain and in Norway. Change of climate, as I have shewn in previous papers, having been much more extensive on the east than on the west side of the Atlantic, owing to the distribution of warm and cold currents resulting from the present elevation of the land.

It cannot be assumed that the fauna of the older part of the Canadian Post-pliocene is different to any great extent from that of the more modern part. Such difference as exists seems to depend merely on a gradual amelioration of climate. The shells of the lower Boulder-clay, and of those more inland and elevated portions of the beds which may be regarded as older than those of the lower terraces near the coast, are undoubtedly more Arctic in character. The amelioration of the climate seems to have kept pace with the gradual elevation of the land, which threw the cold ice-bearing Arctic currents from its surface, and exposed a larger area of land to the action of solar heat, and also probably determined the flow of the waters of the Gulf Stream into the North Atlantic. By these causes the summer heat was increased, the winds both from the land and sea were raised in temperature, and the heavy northern ice was led out into the Atlantic, to be melted by the Gulf Stream, instead of being drifted to the south-west over the lower levels of the continent. Still the cold Arctic currents entering by the Straits of Belle-isle and the accumulation of ice and snow in winter, are sufficient to enable the old Arctic fauna to maintain itself on the Northern side of the Gulf of St. Lawrence, and to extend as far as the latitudes of Murray Bay and Gaspé. South of Gaspé we have the warmer New England fauna of Northumberland Strait. I may add that some of the peculiarities of the Post-pliocene fauna in comparison with that of the St. Lawrence river, indicate a considerable influx of fresh water, derived possibly from melting ice and snow.

PART III.—GENERAL CONCLUSIONS.

This Memoir has already extended to so great length, that I shall be under the necessity of dwelling as little as possible on the general geological truths deducible from the facts which have been stated. I shall specially refer to only two points: (1) The relation of the Post-pliocene fossils to questions of derivation of species; (2) The bearing of the facts above stated on theories of land glaciation.

On the first of these subjects I may remark that whatever may have been the lapse of geological time from the period of the oldest Boulder Clay to that in which we live, and great though the climatal and geographical changes have been, we cannot affirm that any change even of varietal value has taken place in

any of the 205 species of the above lists. This appears to me a fact of extreme significance with reference to theories of the modification of species in geological time. No geologist doubts that the Post-pliocene was a period of considerable duration. The great elevations and depressions of the land, the extensive erosions, the wide and thick beds of sediment, all testify to the lapse of time. The changes which occurred were fruitful in modifications of depth and temperature. Deep waters were shallowed, and the sea overflowed areas of land. The temperature of the waters changed greatly, so that the geographical distribution of marine animals was materially affected. Yet all the Post-pliocene species survive, and this without change. Even variable forms like the species of *Buccinum* and *Astarte* show the same range of variation in the Post-pliocene as in the modern, and though some varieties have changed their geographical position, they have not changed their character. This result is obviously independent of imperfection of the geological record, because there is no reason to doubt that these species have continuously occupied the North Atlantic area, and we have great abundance of them for comparison both in the Post-pliocene and the modern seas. It is also independent of any questions as to the limits of species and varieties, inasmuch as it depends on careful comparisons of the living and fossil specimens; and by whatever names we may call these, their similarity or dissimilarity remains unaffected. We have at present no means of tracing this fauna as a whole farther back. Some of its members we know existed in the Pliocene and Miocene without specific difference; but some day the middle tertiaries of Greenland may reveal to us the ancestors of these shells, if they lived so far back, and may throw further light on their origin. In the meantime we can affirm that the lapse of time since the Pliocene has not sufficed even to produce new races; and the inevitable conclusion is that any possible derivation of one species from another is pushed back infinitely, that the origin of specific types is quite distinct from varietal modification, and that the latter attains to a maximum in a comparatively short time, and then runs on unchanged, except in so far as geological vicissitudes may change the localities of certain varieties. This is precisely the same conclusion at which I have elsewhere arrived from a similar comparison of the fossil floras of the Devonian and Carboniferous periods in America.

The second leading point to which I would direct attention is the relative value of land ice and water-borne ice as causes of geological change in the Post-pliocene. On this subject I have for the last sixteen years constantly maintained that moderate view which has been that of Sir Roderick Murchison and Sir Charles Lyell, that the Post-pliocene subsidence and refrigeration produced a state of our Continent in which the lower levels and at certain periods even the tops of the higher hills were submerged, under water filled every season with heavy ice derived from glaciers, and that at certain stages of submergence the hilly ranges were occupied with glaciers, sending down their ice to the level of the sea. I need not reiterate the arguments for this view; but may content myself with a reference to the changes of opinion on the subject. The glacier theory of Agassiz and others may be said to have grown till, like the imaginary glaciers themselves, it overspread the earth. All northern Europe and America were covered with a mer-de-glace, moving to the southward and outward to the sea. This great ice-mantle not only removed stones and clay to immense distances, and glaciated and striated the whole surface, but it cut out great lake basins and fiords, ground even the tops of the highest hills, and accounted for everything otherwise difficult in the superficial contour of the land. It was even transferred to Brazil, and employed to excavate the valley of the Amazon. But this was its last feat, and it has recently been melting away under the warmth of discussion until it is now but a shadow of its former self. I may mention a few of the facts which have contributed to this result. It has been found that the glacial Boulder-clays are in many cases marine. Cirques and other Alpine valleys, once supposed to be the work of glaciers, are now known to have been produced by aqueous denudation. Great lakes, like those of America, supposed to be inexplicable except by glacier erosion, have been found to admit of being otherwise accounted for. The transport of boulders and direction of striation have been found to conflict with the theory of continental glaciation, or to require too extravagant suppositions to account for them in that way. Greenland, at one time supposed to be a modern example of an ice-clad continent, has been found to be merely a mass of rocky hills and table-lands with local glaciers. The relation of Greenland to Baffin's Bay and Davis Straits, proves to be similar to that which may have obtained between the Laurentide hills and

the submerged valley of the St. Lawrence. Lastly, the power attributed to glaciers as eroding agents, has been found to be altogether fallacious. I was surprised, in visiting the Alps in 1865, to find that this boasted erosive power was little else than a myth; and I see that since that time many other observers have arrived at similar conclusions. I have recently seen a very sensible view of this question in a popular book by the well-known Alpine explorer, Whymper, of which I may quote the concluding paragraph, as precisely stating my own view as expressed in the Canadian Naturalist in 1866:

"If I were asked whether the action of glaciers upon rocks should be considered as chiefly destructive or conservative, I should answer without hesitation principally as conservative. It is destructive certainly to a limited extent; but like a mason who dresses a column that is to be afterwards polished, the glacier removes a small portion of the stone on which it works in order that the rest may be more effectually preserved."*

Some of the ablest of the advocates of the action of continental glaciers have recently in my opinion contributed largely to the overthrow or modification of the theory. I may refer to two examples.

Prof. Dana has given the *coup de grace* to the American continental glacier by his paper in the No. of Silliman's American Journal for November, 1871. In this paper he affirms that "the idea of a central glacier source for the continent is without foundation," so that it comes to be a question of local glaciers. He demands, however, one very large glacier of this kind. South-east striae occur on the mountains of New England to a height of 5000 to 5200 feet above the sea. A glacier to make these must, as he admits, have moved from a higher level. But N.W. of these striated mountains lie the valley of Lake Champlain and the great plain of the St. Lawrence, the latter with S. W. striæ at right angles to those on the mountains. Still farther in the same direction is the valley of the Ottawa, and between this and the great low region of Hudson's Bay is only the Laurentian watershed of about 1500 feet high. From this must have flowed the glacier which passed over the tops of the White Mountains. In order to effect this result, it is necessary to suppose an elevation of the Hudson's Bay watershed in the Post-pliocene period to at least

* Whymper, "Scrambles amongst the Alps."

4,500 feet above its present height, and considering the uneven nature of the intervening country this is far too little. From this imaginary plateau 6000 to 7000 feet high, flowed a glacier over an intervening valley at least 5000 feet deep and thence over the Green and White Mountains. The glacier must consequently have been itself at least 7000 to 8000 feet thick. Farther "on nearing the St. Lawrence the lower part of its mass yielded to the impulse of gravity according to the slopes of this transverse valley, so that along this valley only *southwest* scratches were made." But the southwest scratches of the St. Lawrence valley run from Labrador to the lake region and beyond, and have been produced by a force acting from the northeast, so that the actual fact must have been the flowing of a transverse glacier under the other up the slope of the country, then on the hypothesis probably greater than at present. But the whole assumption of an unequal elevation of the continent, so as to give a mountain region of the required elevation is destitute of proof; and not only so but contrary to the observed facts, which indicate very equable movements of elevation and depression as high at least as the terraces and raised beaches extend. In short, while our continental glacialists demand a glacier that shall move up the St. Lawrence valley and over the Niagara escarpment into Lake Erie, they also demand the creation of a mountain north of the St. Lawrence, high enough to enable a glacier to glide from it over the White Mountains. These extravagant assumptions are fatal to their theory, and shew that they will be driven to have recourse to floating ice to explain a large part at least of the phenomena.

Mr. J. Geikie, one of the most stubborn of land glacialists, is doing a similar service to the cause of truth, in a series of articles now appearing in the London Geological Magazine. He candidly admits that the "evidence which has been accumulating during recent years will compel us to modify materially" the views of the extreme glacialists. He further admits that the Boulder-clay or till contains stratified gravel, clay and sand, with marine shells. He still maintains that the Boulder-clay proper is moraine matter produced on land, though there is evidence that this Boulder-clay as well as the stratified beds included in it, sometimes at least holds marine shells. He further seems to maintain that Boulder-clay proper, being an unstratified deposit, cannot be of marine origin, though this assumption is contro-

verted, first, by the fact that clays full of stones and boulders contain marine shells, and in Canada at least, the boulders imbeded in such hard clays of the nature of till, often have Bryozoa and Acorn-shells attached to them; and, secondly, by the fact that the clays holding numerous boulders sometimes are stratified. Holding, however, his peculiar views about the Boulder-clay, Mr. Geikie must account for it by land glaciers, and the facts, according to him, shew that these could not have been merely a number of small local glaciers, but a general *mer de glace*. To reconcile this with the occurrence of the marine beds, he is obliged to have recourse to a series of cold and warm periods, and of emergences and submergences, some of them of sufficient duration to enable the country to be occupied with forests and with terrestrial mammalia. Thus it becomes necessary to exaggerate the duration of the glacial period, and indeed to invoke the aid, not of one glacial period, but of many, separated from each other by long periods of ameliorated climate. All this would be avoided by at once admitting the existence of marine Boulder-clays, and endeavouring to separate these either by their fossils or by their chemical and mechanical character from the glacial moraines, which I have no doubt will be found in Scotland as in North America to belong merely to local glaciers flowing in the existing valleys. The kames or eskers, which used both in Scotland and this country to be confounded with moraine ridges, Mr. Geikie now, with all other good geologists, regards as marine, though he attributes some of them to an older date than that held by Home and others.

My general conclusion on this subject is therefore precisely what it was many years ago, and that on which I have proceeded throughout this paper; namely, that we have in Canada evidence of a glacial period in which all the hilly ranges above water, were covered with snow and had glaciers in their valleys; these glaciers terminating and giving off icebergs at the mouths of the valleys, where these opened on the plain of the St. Lawrence, then under water. In the earlier part of the period the elevated land of the Pliocene epoch gradually sunk under the waters, and the remainder of it became refrigerated and covered with snow and ice. At the period of greatest subsidence, nearly all the hills were submerged, and heavy ice from the north ground over their summits; while the upper part of the Boulder-clay and the lower beds of the Leda clay were deposited in the valleys.

As the land rose again, ice-clad hills returned, and new though perhaps less extensive glaciers were formed, and fresh crops of boulders were deposited in the shallowing seas of the Saxicava sand period. Snow still exists throughout the summer in the higher ravines of the White Mountains, and on the hills of Labrador, and a subsidence of a few hundred feet in the valley of the St. Lawrence and the country to the southward, would suffice to restore them to the condition of snow-clad hills giving off icebergs from their bases, so near are we yet to the glacial period; and so little did it really differ from that condition of the continent which still exists. I do not here enter into the question of possible astronomical causes of refrigeration suggested by Croll and others. These may have been influential both with reference to changes of level and of temperature; but I believe the changes of level are sufficient to account for the observed facts.

On my return from Europe in 1866, I endeavoured in a popular lecture, printed in Vol. III. N. S. of the Canadian Naturalist, and entitled comparisons of the "Icebergs of Belleisle and the Glaciers of Mont Blanc," to picture the condition of Post-pliocene Canada. I may refer to this paper as more fully stating my conclusions on the subject, and shall close this summary of the results of sixteen years' work in the Post-pliocene, with two extracts referring to the nature of the action of glaciers and the probable state of Post-pliocene Canada.

"Glaciers are mills for grinding and triturating rock. The pieces of rock in the moraine are, in the course of their movement, crushed against one another and the sides of the valley, and are cracked and ground as if in a crushing-mill. Further, the stones on the surface of the glacier are ever falling into crevasses, and thus reach the bottom of the ice, where they are further ground against one another and the floor of rock. In the movement of the glacier these stones seem in some cases to come again to the surface, and their remains are finally discharged in the terminal moraine, which is the waste-heap of this great mill. The fine material which has been produced, the flour of the mill, so to speak, becomes diffused in the water which is constantly flowing from beneath the glacier, and for this reason all the streams flowing from glaciers are turbid with whitish sand and mud.

"The Arve which drains the glaciers of the north side of Mont Blanc, carries its burden of mud into the Rhone, which

sweeps it, with the similar material of many other Alpine streams, into the Mediterranean, to aid in filling up the bottom of that sea, whose blue waters it discolours for miles from the shore, and to increase its own ever enlarging delta which encroaches on the sea at the rate of about half a mile per century. The upper waters of the Rhone, laden with similar material, are filling up the Lake of Geneva; and the great deposit of 'loess' in the alluvial plain of the Rhine, about which Gaul and German have contended since the dawn of European history, is of similar origin. The mass of material which has thus been carried off from the Alps, would suffice to build up a great mountain chain. Thus by the action of ice and water—

> "The mountain falling cometh to naught
> And the rock is removed out of its place."

"Many observers who have commented on these facts have taken it for granted that the mud thus sent off from glaciers, and which is so much greater in amount than the matter remaining in their moraines, must be ground from the bottom of the glacier valleys, and hence have attributed to these glaciers great power of cutting out and deepening their valleys. But this is evidently an error, just as it would be an error to suppose the flour of a grist-mill ground out of the mill-stones. Glaciers it is true groove and striate and polish the rocks over which they move, and especially those of projecting points and slight elevations in their beds, but the material which they grind up is principally derived from the exposed frost-bitten rocks above them, and the rocky floor under the glacier is merely the nether mill-stone against which these loose stones are crushed. The glaciers in short can scarcely be regarded as cutting agents at all, in so far as the sides and bottoms of their beds are concerned, and in the valleys which the old glaciers have abandoned, it is evident that the torrents which have succeeded them have far greater cutting power."

"In conclusion, I would wish it to be distinctly understood, that I do not doubt that at the time of the greatest post-pliocene submergence of Eastern America, at which time I believe the greater part of the boulder clay was formed, and the more important striation effected, the higher hills then standing as islands would be capped with perpetual snow, and through a great part of the year surrounded with heavy field and barrier

ice, and that in these hills there might be glaciers of greater or less extent. Further it should be understood that I regard the boulder clays of the St. Lawrence valley as of different ages, ranging from the early post-pliocene to that at present forming in the gulf of St. Lawrence. Further, that this boulder clay shows in every place where I have been able to examine it, evidence of sub-aquatic accumulation, in the presence of marine shells or in the unweathered state of the rocks and minerals enclosed in it, conditions which, in my view, preclude any reference of it to glacier action, except possibly in some cases to that of glaciers stretching from the land over the margin of the sea, and forming under water a deposit equivalent in character to the 'boue glaciare' of the bottom of the Swiss glaciers. But such a deposit must have been local, and would not be easily distinguishable from the marine boulder clay. I have not had opportunities to study the boulder clay of Scotland, which in character and relations so closely resembles that of Canada, but I confess several of the facts stated by Scottish Geologists lead me to infer that much of what they regard as of sub-aerial origin must really be marine, though whether deposited by ice-bergs or by the fronts of glaciers terminating in the sea, I do not pretend to determine. It must however be observed that the antecedent probability of a glaciated condition is much greater in the case of Scotland than in that of Canada, from the high northern latitude of the former, its more hilly character, and the circumstance that its present exemption from glaciers is due to what may be termed exceptional and accidental geographical conditions; more especially to the distribution of the waters of the Gulf stream, which might be changed by a comparatively small subsidence in Central America. To assume the former existence of glaciers in a country in north latitude 56°, and with its highest hills, under the present exceptionally favourable conditions, snow-capped during most of the year, is a very different thing from assuming a covering of continental ice over wide plains more than ten degrees farther south, and in which, even under very unfavourable geographical accidents, no snow can endure the summer sun, even in mountains several thousand feet high. Were the plains of North America submerged and invaded by the cold Arctic currents, the Gulf stream being at the same time turned into the Pacific, the temperature of the remaining North American land would be greatly diminished; but under these circumstances the climate

of Scotland would necessarily be reduced to the same condition with that of South Greenland or Northern Labrador. As we know such a submergence of the land to have occurred in the Post-pliocene period, it does not seem necessary to have recourse to any other cause for either side of the Atlantic. It would, however, be a very interesting point to determine, whether in the Post-pliocene period the greatest submergence of America coincided with the greatest submergence of Europe, or otherwise. It is quite possible that more accurate information on this point might remove some present difficulties. I think it much to be desired that the many able observers now engaged on the Post-pliocene of Europe, would at least keep before their minds the probable effects of the geographical conditions above referred to, and enquire whether a due consideration of these would not allow them to dispense altogether with the somewhat extravagant theories of glaciation now agitated."

It is hardly necessary to add that I hold and have endeavoured to prove by modern facts, in the Memoirs above referred to, that heavy icebergs borne by powerful currents, are potent agents in the production of striated surfaces and glaciated stones, as well as in transporting boulders, and that cold ocean currents are powerful eroding agents, especially when aided by heavy ice. Witness the Straits of Belle-Isle in modern times. Mr Vaughan, for many years Superintendent of the Lighthouse at that place, states that for ten icebergs which enter the straits fifty drift to the southward, yet he records that on the 30th of May, 1858, he counted in the Strait of Belle-Isle 496 bergs, the least of them sixty feet in height, some of them half a mile long and two hundred feet high. Only one-eighth of the volume of floating ice appears above water, and many of these great bergs may thus touch the ground in a depth of thirty fathoms or more, so that if we imagine four hundred of them moving up and down under the influence of the current, oscillating slowly with the motion of the sea, and grinding on the rocks and stone-covered bottom at all depths from the centre of the channel, we may form some conception of the effects of these huge polishers of the sea-floor.

If this memoir had not already extended to too great length, I could have wished to notice the evidence as to the existence of ice-action in more ancient periods than the Post-pliocene. I

would now merely state my belief that some of the considerations which render it necessary to invoke the action of frost and ice in the Post-pliocene period, apply also to the origin of some rocks of much higher antiquity. Ramsay has already noticed this in the case of the Permian conglomerates of England. In Canada an instance occurs in the conglomerate with boulders two feet in diameter, found in the Lower Silurian of Maimanse, Lake Superior.* A still more remarkable case is that of the New Glasgow conglomerate in the coal formation of Nova Scotia, which seems to be a gigantic esker, on the outside of which large travelled boulders were deposited, probably by drift ice, while in the swamps within, the coal flora flourished and fine mud and coaly matter were accumulated.†

A second indication of the existence of intense frost in ancient geological periods, is afforded by the occurrence of angular fragments of hard rocks cemented together. Such beds of angular fragments and chips, occur locally at various horizons, for example in the Upper Silurian and Lower Carboniferous in Nova Scotia, and the material of which they are composed seems precisely similar to that which is at present produced by the disintegrating action of frost on hard and especially schistose and jointed rocks. Such deposits may, I think, fairly be regarded as evidence of somewhat intense winter cold.

SUPPLEMENTARY NOTE.—A visit to Nova Scotia while these sheets were going through the press enables me to add the following facts: (1.) The discovery by Mr. G. F. Matthews of shells of Tellina Grœnlandica in the Post-pliocene gravel at Horton Bluff, Nova Scotia. (2.) The occurrence of Laurentian boulders, probably from Labrador, in the Carboniferous region of Nova Scotia. I may specially mention a very fine boulder of Labradorite near the mouth of Carribou River, Pictou County. In Nova Scotia, however, as well as in Prince Edward Island, native stones predominate in the lower Boulder-clay, and the foreign blocks appear more toward the surface; where also, in many cases the greater part of the blocks derived from neighbouring heights are collected. I had occasion often to notice the fact, referred to above, of drift from the south as well as from the north, and also the great frequency in the boulder deposits of glaciated stones.

---

* Can. Nat. II, p. 6. † Acadian Geology, p. 324.